RENEWABLE ENERGY INTEGRATION PLAN

Phase 3: Renewable Energy Resource Assessment And Development Program

November 1995

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SECTION 1. INTRODUCTION AND BACKGROUND

RLA Consulting (RLA) has been retained by the State of Hawaii Department of Business, Economic Development, & Tourism (DBEDT) to conduct a Renewable Energy Resource Assessment and Development Program. This three-phase program is part of the Hawaii Energy Strategy (HES), which is a multi-faceted program intended to produce an integrated energy strategy for the State of Hawaii. This report summarizes the results of Phase 3 of the program, including a Renewable Energy Integration Plan for the State of Hawaii.

BACKGROUND

In Phase 1 of the Renewable Energy Resource Assessment and Development Program, suitable locations with development potential for renewable energy projects were identified. The emphasis for project identification was on utility-scale, grid-connected renewable energy projects. For each of the technologies under consideration, a potential project list was developed based on an elimination process of the available land on each of the six major Hawaiian islands: Hawaii, Maui, Lanai, Molokai, Oahu, and Kauai. For each island, geographic areas were identified in which resource potential exists, then an in-depth screening process was conducted that included consideration of factors such as land ownership, zoning, current and planned land uses, technology-specific development requirements, utility access and impact, environmental constraints, and public acceptance. Additional information on the methodology, assumptions, and results of Phase 1, along with a description of each project site are included in the Phase 1 report, *Renewable Energy Resource Assessment Plan.*

In Phase 2, detailed cost and performance estimates were developed for each of the potential projects identified in Phase 1. Tables 1-1 to 1-4 list the potential renewable energy projects and project sizes that were evaluated as part of this program. These projects represent viable development opportunities, with no foreseeable technical or institutional barrier, on each island and for each technology. Although no project sites are included in the database for either Lanai or Molokai, there is potential on these islands for small-scale renewable energy applications. On these islands, the size of the utility grid, the extent of the existing renewable energy projects, and the projections for demand growth limit consideration of any additional utility-scale renewable energy projects at this time. Small-scale applications for renewable energy technologies are discussed Section 5.

In order to estimate costs and performance for renewable energy projects in Hawaii, RLA compiled the most current cost and performance data for each of the renewable energy conversion technologies evaluated in the project. Technologies included wind, solar thermal (troughs and dishes), photovoltaics (fixed and tracking), biomass electricity (with energy crops and/or organic waste as a fuel source), biomass fuel (both methanol and ethanol), hydroelectric, wave, ocean thermal, and geothermal.

For most technologies, two conceptual plant designs were developed. One design was based on plant components that are commercially available for installation in 1995 (current technology). The other design was based on components that are realistically expected to be commercially deployed by the year 2005 (future technology). In the case of technologies that have not been commercially deployed, estimates were only made for the future scenario. For mature technologies in which no substantial technological advances are expected, estimates were developed for only the current scenario.

In order to account for the uncertainty in cost and resource projections, three estimates (representing optimistic, nominal, and conservative cases) were made for each potential project and for both states of technology development (current and future). As a result, a total of six cost and energy estimates were made for each potential project location and size for the majority of the technologies evaluated. The optimistic, nominal, and conservative cases differ from each other because of uncertainty in the energy projections, project costs, or a combination of both.

Table 1-1. Potential Projects, Island of Hawaii

Technology	Project Location	Size (MW)
Wind	Kahua Ranch	5, 15
	Lalamilo Wells	3, 30, 50
	N. Kohala	5, 15
Solar Thermal		
Dishes	Keahole	30
	N. Kohala	5, 15
	Waikoloa	30
Trough	Keahole	30
	Waikoloa	30
Photovoltaic		
Fixed	Keahole	30, 50
	N. Kohala	5, 15
	Waikoloa	30, 50
Tracking	Keahole	30, 50
	N. Kohala	5, 15
	Waikoloa	30, 50
Biomass Electric		
Grass Crops	Hamakua Coast	25
	Hilo Coast	25
	Ka'u	25
Tree & Organic Waste	Hilo Coast	50
Tree Crops	Hamakua Coast	25
	Hilo Coast	25
Biomass Fuel-Methanol		
Grass Crops	Kaumakai	25 MGPY
Tree Crops	Hamakua Coast	25 MGPY
	Hilo Coast	25 MGPY
Hydro	Umauma Stream	13.8
Wave	Honokaa	10
	N. Kohala	10, 30
	Pepeekeo	10
Ocean Thermal	Keahole Point	60
Geothermal	Kilauea East Rift Zone	25, 50

Note: Project size is given in MW of installed capacity except biomass-fuels, which are given in millions of gallons per year.

Table 1-2. Potential Projects, Island of Maui

TECHNOLOGY	PROJECT LOCATION	SIZE (MW)
WIND	MCGREGOR POINT	30
	NW HALEAKALA	10, 30, 50
	PUUNENE	10, 30
	WEST MAUI	10, 30, 50
SOLAR THERMAL		
DISHES	KAHULUI	10, 30
	KIHEI	10, 30
	PUUNENE	10, 30
TROUGH	KAHULUI	30
	KIHEI	30
	PUUNENE	30
PHOTOVOLTAIC		
FIXED	KAHULUI	10, 30
	KIHEI	10, 30
	PUUNENE	10, 30
TRACKING	KAHULUI	10, 30
	KIHEI	10, 30
	PUUNENE	10, 30
BIOMASS ELECTRIC		
ORGANIC WASTE	PAIA-PUUNENE	25
GRASS CROPS	PAIA-PUUNENE	25, 50
TREE CROPS	PAIA-PUUNENE	50
BIOMASS FUEL-ETHANOL		
GRASS CROPS	PAIA-PUUNENE	25, 50 MGPY
TREE CROPS	PAIA-PUUNENE	25 MGPY
BIOMASS FUEL-METHANOL		
ORGANIC WASTE	PAIA-PUUNENE	25 MGPY
GRASS CROPS	PAIA-PUUNENE	50 MGPY
TREE CROPS	PAIA-PUUNENE	50 MGPY
WAVE	LOWER PAIA	10, 30, 60
	OPANA POINT	10, 30, 60
	WAIEHU POINT	10, 30

NOTE: PROJECT SIZE IS GIVEN IN MW OF INSTALLED CAPACITY EXCEPT BIOMASS-FUELS, WHICH ARE GIVEN IN MILLIONS OF GALLONS PER YEAR.

Table 1-3. Potential Projects, Island of Oahu

TECHNOLOGY	PROJECT LOCATION	SIZE (MW)
WIND	KAENA POINT	2, 15
	KAHUKU	30, 50, 80
SOLAR THERMAL		
DISHES	LUALUALEI	50
	N. EWA PLAIN	50
	PEARL HARBOR	50
TROUGH	LUALUALEI	80
	N. EWA PLAIN	80
	PEARL HARBOR	80
PHOTOVOLTAIC		
FIXED	LUALUALEI	10, 20, 50
	N. EWA PLAIN	10, 50
	PEARL HARBOR	10, 50
TRACKING	LUALUALEI	10, 20, 50
	N. EWA PLAIN	10, 50
	PEARL HARBOR	10, 50
BIOMASS ELECTRIC		
ORGANIC WASTE	BARBERS POINT	50
GRASS CROPS	WAIALUA	25
BIOMASS FUEL		
ORGANIC WASTE-ETHANOL	BARBERS POINT	25 MGPY
ORGANIC WASTE-METHANOL	BARBERS POINT	50 MGPY
WAVE	MAKAPUU	30, 60
	MOKAPU POINT	30
	N.E. COAST (UPPER)	30
	N.E. COAST (LOWER)	30
	WAIMANALO	30
	KAHUKU POINT	30, 60
OCEAN THERMAL	KAHE POINT	60

NOTE: PROJECT SIZE IS GIVEN IN MW OF INSTALLED CAPACITY EXCEPT BIOMASS-FUELS, WHICH ARE GIVEN IN MILLIONS OF GALLONS PER YEAR.

Table 1-4. Potential Projects, Island of Kauai

Technology	Project Location	Size (MW)
Wind	Anahola	7
	N. Hanapepe	10
	Port Allen	5
Solar Thermal		
Dishes	Barking Sands	10
Photovoltaic		
Fixed	Barking Sands	10
Tracking	Barking Sands	10
Biomass Electric		
Grass Crops	Kaumakani	25
	Lihue	25
Tree & Organic Waste	Kaumakani	50
Tree Crops	Kaumakani	25
	Lihue	25
Biomass Fuel-Methanol		
Tree Crops	Kaumakani	25 MGPY
	Lihue	25 MGPY
Hydro	Wailua River	6.6
Wave	Anahola	10, 30
	Barking Sands	10, 30

Note: Project size is given in MW of installed capacity except biomass-fuels, which are given in millions of gallons per year.

A user-friendly, Resource Supply Curve (RSC) computer model was then developed to calculate the levelized cost of energy (in 1995 dollars) for each project based on the Electric Power Research Institute Technical Assessment Guide (EPRI TAG) methodology, a common set of economic parameters, and the site-specific cost and performance estimates. The program calculates the cost of energy for each project and displays a graphical summary of the results of a specific query.

The RSC model provides a choice of evaluating projects based on two valuation methods and two basic financing options. The valuation methods include constant dollar analysis (no inflation) or current dollar analysis. Financing options include either utility or non-utility financing. To maximize the flexibility of the program, the user has the further option of changing the debt/equity ratios, the tax life, the inflation rate, the debt cost, the equity cost, the property tax, and the state and federal income tax credits to values other than the default values. Additional information on the use and assumptions incorporated into the RSC model, as well as the detailed cost and performance estimates for each project, are included in the Phase 2 report, *Development of Renewable Energy Resource Supply Curves.*

OBJECTIVES OF PHASE 3

The RSC program was developed to provide the user with a tool to compare various options under differing conditions. The objective of Phase 3 of the Renewable Energy Resource Assessment and Development Program is to concentrate on the integration and interpretation of the data by using the RSC model as an analysis tool. This reports presents the results of this analysis and draws conclusions for integrating renewable energy projects into the state's generation mix.

Another objective of Phase 3 was to collect additional wind and solar resource data from sites which appeared to have development potential but for which high-quality data were not publicly available. More than a year of data was collected at 8 wind sites and 5 solar sites. The cost and performance estimates for the wind and solar projects have been updated based on these new data. Summaries of the actual data that were collected under Phase 3, as well as summaries of the historical data that were utilized in the project, are included in a separate report.

REPORT ORGANIZATION

The report is organized into six sections. Following this introduction, Section 2 summarizes the results of the program for 1995, assuming current renewable energy technology and current economic conditions. Section 3 summarizes the results of the program for 2005, assuming future renewable energy technology and projections of future energy demand and costs. Section 4 discusses renewable energy project implementation in the State of Hawaii and includes a renewable energy integration plan for each island. The renewable energy integration plans are based on the 2005 results for each island given the constraints and limitations to project development that exist on that island. They represent a set of realistic goals for incorporating renewables into Hawaii's generation mix. Section 5 presents project implementation analyses for intermittent generating resources such as wind, solar, and wave projects. These analyses, which include load matching, capacity value, and time-of-day pricing, can impact the value an intermittent resource has to a utility system. Section 6 contains conclusions and recommendations.

SECTION 2. RESULTS FOR THE RESOURCE SUPPLY CURVE MODEL FOR 1995

This section discusses the renewable energy projects that appear to be economically and technically feasible for installation in 1995 under the set of assumptions presented. The assumptions in the RSC model may be changed to test other development scenarios or to adapt the results to changing conditions. Because these projects are not currently under development and are therefore not likely to be put in service in 1995, this evaluation is somewhat academic. However, the results highlight what might have been done if more information was available on the resource potential several years ago assuming the institutional requirements such as power purchase contracts, tax credits, land owner interest, and utility and/or independent power producer development interest also existed.

The 1995 results also provide a solid basis on which to plan future actions. Projects already shown to be economical, based on 1995 conditions, can be evaluated in more detail and placed in service over the next few years to provide cost savings for both the Hawaiian utilities and their customers. These projects can then form the basis for other, well characterized projects that will be economical by the year 2005.

ANALYSIS APPROACH

As previously discussed, the RSC model enables the user to evaluate the results from three possible cost and performance scenarios: nominal, conservative, and optimistic. The range in these estimates represents the variation in the technological development of each technology as well as the uncertainty in the resource. Hawaii can play a part in narrowing the range by participating in fundamental research or demonstration projects and by additional resource assessment; however, much of the variation is due to uncertainty in the pace of technology development over which the state generally has little influence.

In this section, results are presented for each of the three scenarios. Because the islands are not electrically interconnected, the analyses were carried out on an island-by-island basis. The nominal scenario, which reflects the most likely productivity and costs of the projects, is discussed as the base case.

Unless otherwise stated, utility financing and current state and federal tax credits were assumed for all 1995 projects. The base case analyses also include all required transmission costs to support the projects under consideration. The impacts of varying these assumptions are discussed later in this section. All analyses in this report were conducted in constant dollars.

To establish how much energy from renewable energy projects is cost-competitive with the local utility's current energy production costs, levelized cost of energy for each project is compared to the utility's avoided energy cost. Avoided energy cost represents the cost for the utility to generate additional electricity, it does not account for all potential utility impacts such as avoided or deferred system improvements or non-utility avoided costs (externalities). A vertical line representing this avoided cost was generated on the RSC graphs for each island. Projects to the left of this line on the RSC graphs represent projects that are cost-competitive (can be implemented at a levelized cost of energy that is lower than the current cost for the utility to supply the same amount of energy). Projects to the right of the line are more expensive than the utility's avoided energy cost. While the utility's avoided energy cost is expected to escalate over the lifetime of any proposed renewable energy project (further improving the comparison) the effect of this escalation has not been incorporated into the comparisons.

The annual benefits to Hawaii from implementing the viable renewable energy projects can be quantified by calculating the area under the curve and to the left of the vertical, avoided energy cost line. This benefit represents the net savings to the utility and its customers from using renewable energy projects rather than the generating units which form the basis of avoided energy costs.

In the following sections, the 1995 results are summarized for each island in terms of the amount of electricity that could be generated and the annual cost savings realized from implementing the viable projects. Results are provided for each development scenario by island. The impact of varying the assumptions is also evaluated. Note that although each of the projects discussed is viable independently, the entire list of projects for each island may not be viable as a group. For example, the total amount of electricity that could be generated from viable projects may be greater than the demand on that particular island, or more than the local utility can accommodate. In this section, all viable projects are presented and discussed. The constraints to developing the projects individually and as a group are discussed in more detail in Section 4. The results are combined into a realistic renewable energy implementation goal that considers the limitations of both the technology and the utility structure.

1995 RESULTS FOR THE ISLAND OF HAWAII

Resource supply curves for the base case, conservative, and optimistic scenarios which list all the projects on Hawaii and their calculated cost of energy are included in Appendix A.

BASE CASE

Figure 2-1 shows the base case resource supply curve for the Island of Hawaii. For 1995, the average avoided energy cost for Hawaiian Electric Light Company (HELCO) was estimated to be approximately \$0.0556/kWh. The avoided energy cost estimate was based on information provided in HELCO's most recent Integrated Resource Planning (IRP) document.

As shown in the graph, there are three viable wind energy projects on Hawaii that could be implemented in 1995 at a more economical cost than the utility's avoided energy cost: North Kohala, Lalamilo Wells, and Kahua Ranch. The graph shows the most cost-effective project size at each project site. Other project sizes evaluated at all three sites are also viable options, including a larger wind project at Kahua Ranch which requires a transmission line upgrade.

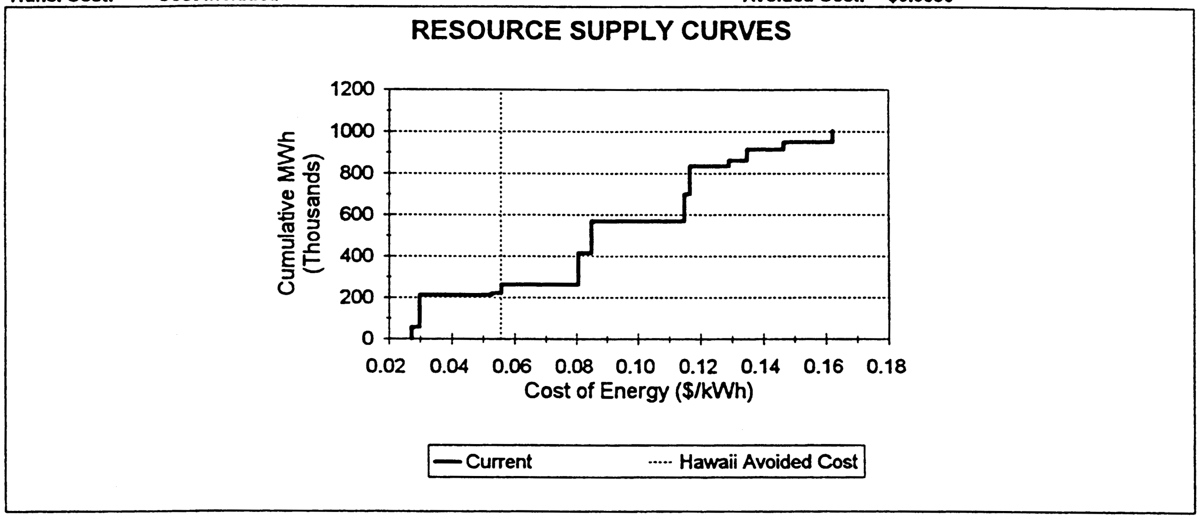
Even with just these three projects, the annual benefits to Hawaii are considerable. The area under the curve reflects the annual savings potential from implementing these three projects. Rather than spending \$12.3 million per year (5.56 cents for each of the 221.6 million kWh), the island utility could instead spend \$6.7 million for the same energy. The difference between these values is approximately \$5.6 million, or the area under the curve (remember, however, that these projects may not be viable as a group, and the project owner(s) would likely require payment of more than their cost to generate).

OPTIMISTIC AND CONSERVATIVE CASES

Under the optimistic assumptions in the model, one additional project on Hawaii, a 13.8 MW hydroelectric facility on Umauma Stream, is shown to be viable.

Under conservative assumptions, all the project sizes for the wind projects at both the Lalamilo Wells and North Kohala are still viable. This result is significant in that it illustrates the quality of the wind resource that is available at these two sites. Lalamilo Wells has long been identified as a good wind site and several

Island(s):	**Hawaii**		**Valuation:**	**Constant Dollars**
Technology:	**All_Tech**		**Financing:**	**Utility**
Certainty:	**Nominal**		**Tax Credits:**	**Included**
Stage:	**Current Technology**		**Data:**	**Unique Location Lowest COE**
Trans. Cost:	**Cost Included**		**Avoided Cost:**	**$0.0556**



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	MWh	COE
Wind		Hawaii	North Kohala	Current	Incl	Nominal	15	56,905	0.0272
Wind		Hawaii	Lalamilo Wells	Current	Incl	Nominal	50	154,183	0.0297
Wind		Hawaii	Kahua Ranch	Current	Incl	Nominal	5	10,516	0.0527
				Energy Produced below Avoided Cost				221,604	
				Annual Savings Potential from Renewables				$5,634,024	

Figure 2-1. 1995 Base Case Resource Supply Curve, Island of Hawaii

wind energy development projects have been proposed for this site. The discovery of the high wind resource at the North Kohala site is one of the positive outcomes resulting from the monitoring program. Prior to the implementation of the monitoring program, there was no wind data available at this site.

1995 RESULTS FOR THE ISLAND OF MAUI

Resource supply curves for the base case, conservative, and optimistic scenarios which list all the projects on Maui and their calculated cost of energy are included in Appendix B.

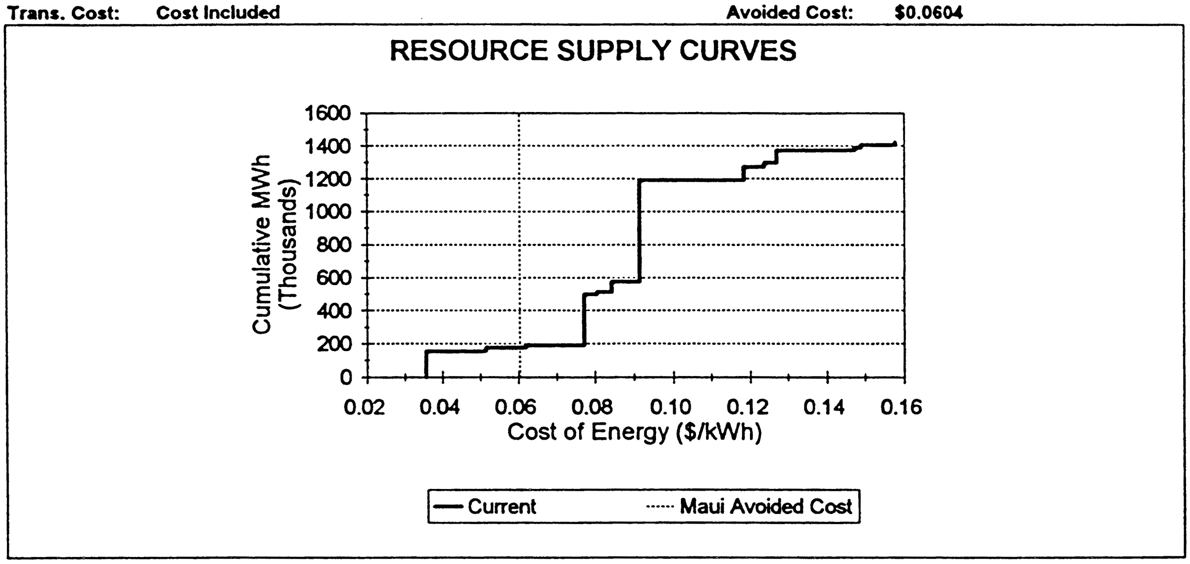
BASE CASE

Figure 2-2 shows the base case resource supply curve for the Island of Maui. For 1995, the avoided energy cost for Maui Electric (MECO) was estimated to be approximately $0.0604/kWh. The avoided energy cost estimate was based on information provided in MECO's most recent IRP document.

As shown in the graph, there are two viable renewable energy projects on Maui that could be implemented in 1995 at a more economical cost than the utility's avoided energy cost: a biomass electric project using organic waste as the fuel source and a wind project at McGregor Point. The costs associated with the biomass electric project assume that the project receives a revenue for waste disposal roughly equivalent to the tipping fees currently charged at the local landfill. As a result of this assumption, the biomass projects using organic waste as a fuel source are generally more cost-effective than other biomass projects.

The area under the curve reflects the annual savings potential from implementing these two projects. Rather than spending $10.5 million per year (6.04 cents for each of the 173.2 million kWh), the island utility could instead spend $6.6 million for the same energy. The difference between these values is approximately $3.9 million, or the area under the curve.

Island(s):	**Maui**	**Valuation:**	**Constant Dollars**
Technology:	**All_Tech**	**Financing:**	**Utility**
Certainty:	**Nominal**	**Tax Credits:**	**Included**
Stage:	**Current Technology**	**Data:**	**Unique Location Lowest COE**
Trans. Cost:	**Cost Included**	**Avoided Cost:**	**$0.0604**



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	MWh	COE
Biomass Elec	org waste	Maui	Puunene	Current	Incl	Nominal	25	153,300	0.0357
Wind		Maui	McGregor Point	Current	Incl	Nominal	10	19,874	0.0515
				Energy Produced below Avoided Cost				173,174	
				Annual Savings Potential from Renewables				$3,967,581	

Figure 2-2. 1995 Base Case Resource Supply Curve, Island of Maui

OPTIMISTIC AND CONSERVATIVE CASES

Under the optimistic assumptions in the model, two additional projects on Maui, a wind project on the northwest side of Haleakala and a biomass electric project using tree crops as the fuel source, become viable. For the NW Haleakala wind site, all three project sizes (10, 30, and 50 MW) are viable under the optimistic scenario.

Under conservative assumptions, only the biomass electric project using organic waste as a fuel source appears to be viable. The wind project at McGregor Point is not considered to be viable under the conservative scenario because the uncertainty of the wind resource is reflected in the conservative energy production estimates. Previous studies have indicated a high wind resource at this site; however, the existing data are of poor quality and it was not possible to monitor the site as part of the Phase 3 monitoring activities due to the disposition of the land lease holder at the time the monitoring program was organized. Additional monitoring could reduce the uncertainty associated with this project.

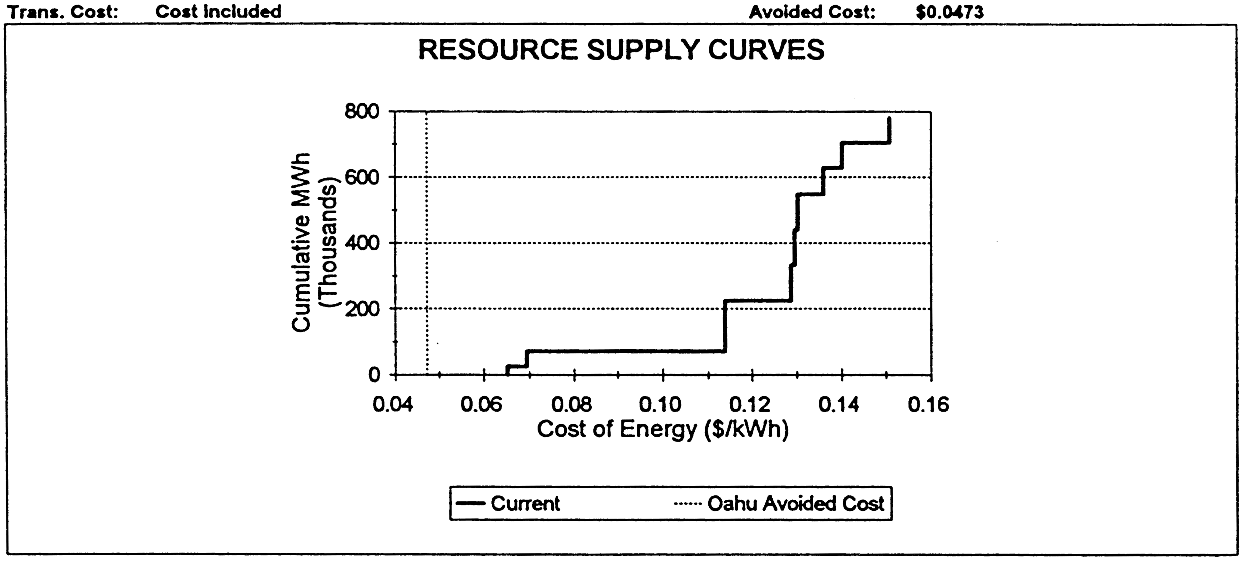
1995 RESULTS FOR THE ISLAND OF OAHU

Resource supply curves for the base case, conservative, and optimistic scenarios which list all the projects on Oahu and their calculated cost of energy are included in Appendix C.

BASE CASE

Figure 2-3 shows the base case resource supply curve for the Island of Oahu. For 1995, the avoided energy cost for Hawaiian Electric Company (HECO) was estimated to be approximately $0.0473/kWh. The avoided energy cost estimate was based on information provided in HECO's most recent IRP document.

Island(s):	Oahu	**Valuation:**	Constant Dollars
Technology:	All_Tech	**Financing:**	Utility
Certainty:	Nominal	**Tax Credits:**	Included
Stage:	Current Technology	**Data:**	Unique Location Lowest COE
Trans. Cost:	Cost Included	**Avoided Cost:**	$0.0473



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	MWh	COE
				Energy Produced below Avoided Cost				0	
				Annual Savings Potential from Renewables				$0	

Figure 2-3. 1995 Base Case Resource Supply Curve, Island of Oahu

As shown in the graph, there are no viable renewable energy projects on Oahu that could be implemented in 1995 at a more economical cost than the utility's avoided energy cost. This result is consistent with the fact that renewable energy projects are not currently under consideration on this island for 1995. An expansion or upgrade of the existing wind project at Kahuku may be more economical than shown in the analysis because some of the infrastructure to support a project already exists at that site; but this is not considered in the RSC database costs. Additional development has been proposed at this site.

OPTIMISTIC AND CONSERVATIVE CASES

Even under the optimistic assumptions in the model, there are no viable renewable energy projects on Oahu that could be implemented in 1995 at a cost more economical than the utility's avoided energy cost. The avoided energy cost on Oahu is the lowest in the state and the levels for 1995 used in the study are even lower than have been experienced in the past.

Wind projects at Kaena Point and Kahuku are the projects closest to being viable. Under optimistic assumptions, a 15 MW project at Kaena Point is approximately 12% more expensive than the utility's avoided energy cost. The next most cost-effective technology is a biomass electric project at the Waialua sugar facility. Although this project does not appear to be economical for 1995, additional benefit may be gained from implementing a project of this type so as to maintain a percentage of land on this island in agriculture. In addition, the biomass project would provide a dispatchable power source. Additional analyses, such as a cost sensitivity analysis assuming different fuel crops, may be warranted at this site.

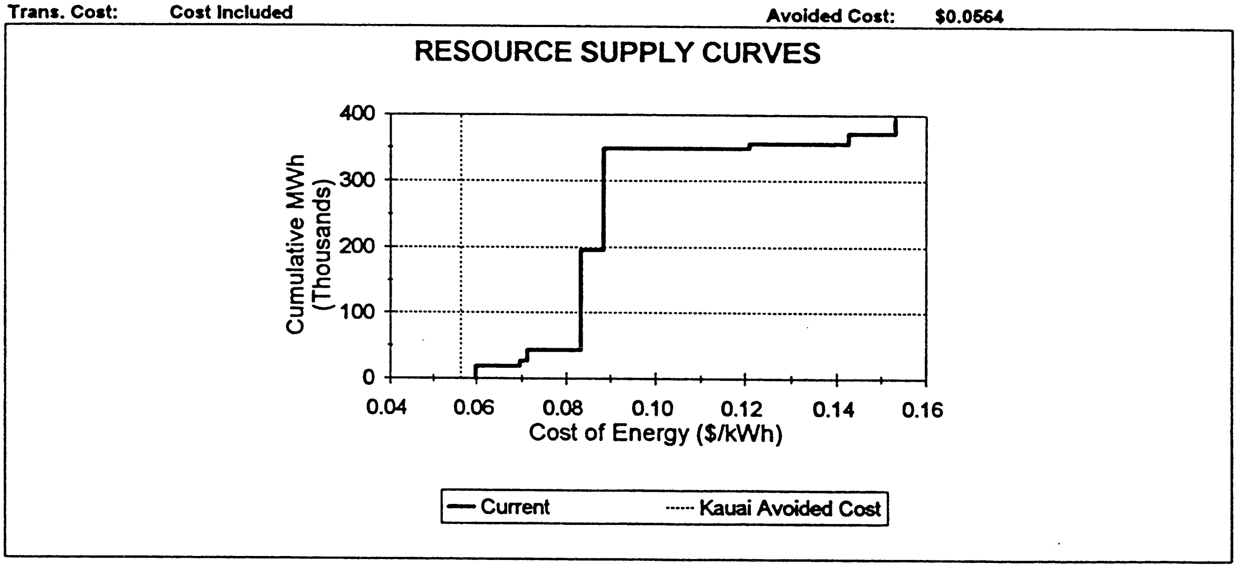
1995 RESULTS FOR THE ISLAND OF KAUAI

Resource supply curves for the base case, conservative, and optimistic scenarios which list all the projects on Kauai and their calculated cost of energy are included in Appendix D.

BASE CASE

Figure 2-4 shows the base case resource supply curve for the Island of Kauai. For 1995, the avoided cost for Kauai Electric Company (KECO) was estimated to be approximately $0.0564/kWh. The avoided energy cost estimate was based on information provided in KECO's most recent IRP document.

Island(s):	Kauai	**Valuation:**	Constant Dollars
Technology:	All_Tech	**Financing:**	Utility
Certainty:	Nominal	**Tax Credits:**	Included
Stage:	Current Technology	**Data:**	Unique Location Lowest COE
Trans. Cost:	Cost Included	**Avoided Cost:**	$0.0564



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	MWh	COE
				Energy Produced below Avoided Cost				0	
				Annual Savings Potential from Renewables				$0	

Figure 2-4. 1995 Base Case Resource Supply Curve, Island of Kauai

As shown in the graph, there are no viable renewable energy projects on Kauai that could be implemented in 1995 at a cost more economical than the utility's avoided energy cost. This result is due in part to the fact that utility demand, zoning restrictions, and competing land uses prevent consideration of large (greater than 10 MW) wind energy installations on Kauai.

OPTIMISTIC AND CONSERVATIVE CASES

Under the optimistic assumptions in the model, two small wind projects appear to be viable: a 10 MW project north of Hanapepe and a 5 MW project near Port Allen. These two projects combine for a total of 30.4 million kWh and an annual savings potential of approximately $0.2 million.

The next most cost-effective technology for deployment in 1995 is a biomass electric project using tree crops. This 25 MW project is approximately 10% more expensive than the utility's avoided energy cost.

IMPACT OF VARYING THE 1995 BASE CASE ASSUMPTIONS

There are a number of policy-related uncertainties that are unrelated to the technology development scenario yet impact the base case results. These factors include financing terms and conditions, the inclusion of transmission upgrade costs, and the application of state and federal tax credits. For the nominal base case results and the optimistic and conservative results discussed above, the following factors were assumed:

1. Utility financing;
2. The inclusion of all costs associated with any additional transmission investment that might be required (some projects did not require transmission upgrades); and
3. Tax credits currently offered at federal and state levels.

To determine the impact that each of these assumptions has on the results, sensitivity studies were run for each of the following conditions:

1. Non-utility financing, which raises the cost of energy for the developer due to less favorable financing terms;
2. The assumption that the project does not have to pay for any additional transmission costs (due to the fact that upgrades may be underway for other reasons); and
3. No tax credits or accelerated depreciation are available to renewable energy projects due to changes in legislation.

The results of these sensitivity studies are summarized below.

NON-UTILITY FINANCING

If non-utility financing is assumed, the financial requirements for developing a power generation project are more demanding and the resulting costs of energy are higher. The higher cost of financing shifts the resource supply curves to the right, which in some cases results in project investments appearing less attractive when compared to the utility financing option. To evaluate the impact of varying this assumption, sensitivity studies were run for the nominal base cases using non-utility financing assumptions and leaving all other variables unchanged.

Figure 2-5 shows an example for the island of Hawaii which illustrates the shift in the graph due to non-utility financing. As shown on the graph, the projects which were viable under the utility financing option are still viable with non-utility financing. However, the net financial benefit, or the area under the curve, is smaller. The same result holds true for the other islands. Projects with non-utility financing are still viable but have slightly higher costs and the annual savings potential for the island is smaller.

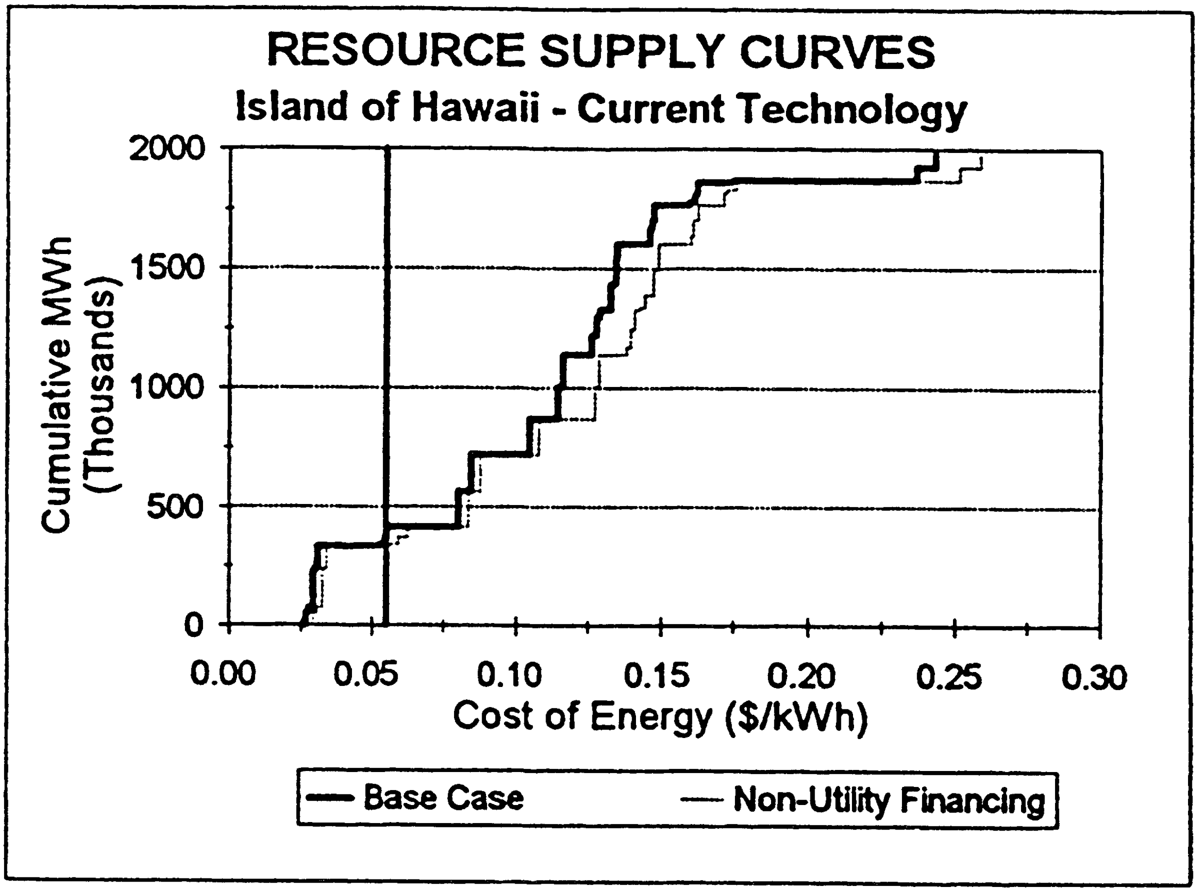


Figure 2-5. Sensitivity Analysis, Financing Options

TRANSMISSION INVESTMENT REQUIREMENT

Eliminating the need for investment in transmission lines for projects that require transmission upgrades would obviously reduce the cost of energy from those projects. Sensitivity studies were run for the nominal base cases assuming any required upgrade costs were not included in the project costs and leaving all other variables unchanged. This scenario could result if the utility upgraded the transmission line for reasons other than to support the renewable energy project under consideration. For example, a 15 MW wind energy project at North Kohala requires a transmission upgrade; however, resort development and county water wells are also being considered in the North Kohala area and transmission upgrades to support these activities may be undertaken and paid for by another entity (or shared between interested parties). In some cases, more than one project may include costs for the same transmission line. For example, a new transmission line to support a project at North Kohala may result in sufficient capacity that a project at Kahua Ranch could also be developed without incurring any additional transmission costs.

This sensitivity analysis is not conducted to illustrate that transmission upgrades may not be necessary. It is just a question of who pays for the upgrade and whether these costs should be incurred by the project. In terms of cost of energy, the investment must be recovered regardless of who makes the investment and ultimately the electricity consumers pay for it in either case. The sensitivity shows only whether transmission investment is important enough to affect the developer's economics.

Figure 2-6 shows an example of this sensitivity study for the island of Hawaii. For the 1995 results, transmission costs only impact the viability of the larger Kahua Ranch wind energy project. Without including the required transmission costs, the larger Kahua Ranch project becomes viable under the nominal base case scenario.

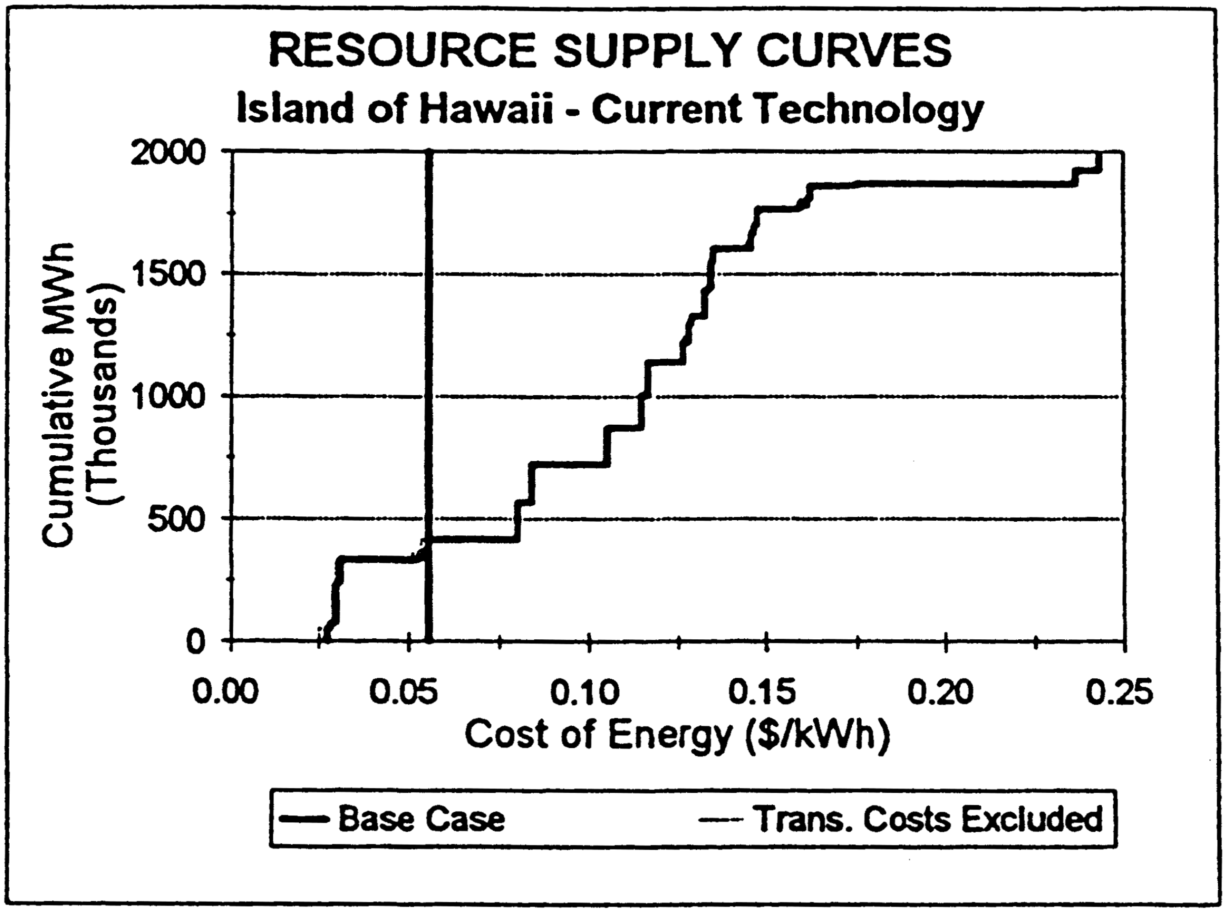


Figure 2-6. Sensitivity Analysis, Transmission Costs

TAX INCENTIVES

Both the federal government and the State of Hawaii offer tax credits for renewable energy projects. To determine whether these incentives impact the 1995 results, sensitivity studies were run for the nominal base cases assuming no tax credits or accelerated depreciation and leaving all other variables unchanged.

The loss of tax credits increases the cost of energy for the viable projects and decreases the net financial benefit significantly. Figure 2-7 shows an example for the island of Hawaii which illustrates the shift in the graph due to the loss of tax credits. Currently, wind, solar, and biomass are the only renewable technologies that receive tax credits.

SUMMARY OF 1995 RESULTS

Several conclusions are apparent from an examination of the RSC model results for 1995. The islands of Hawaii and Maui have the most opportunity in the near term for cost-competitive renewable energy project development. On Oahu, no projects appear to be immediately viable and on Kauai, limited opportunities exist, even under optimistic conditions. Table 2-1 summarizes the projected benefits or savings to the state from each of the cases that were analyzed.

On Hawaii, the three wind projects identified are extremely cost competitive with the current generating units. For all practical purposes, these projects are economic regardless of the assumptions that are made. Under optimistic assumptions, two more renewable energy projects can be implemented cost-effectively on this island. The amount of energy that can be supplied to Hawaii each year from wind power projects is noteworthy. In the nominal case, 221.6 million kWh can be generated which forms about approximately 23% of HELCO's generation.

There are several reasons why these projects have not been implemented despite the favorable economics. First, wind projects have been implemented at some sites on Hawaii although most of them were installed more than ten years ago. These projects utilized older technology that was not as cost effective as today's wind turbines and, as a result, were not financially successful. This experience has resulted in a low confidence level in wind technology. Other issues limiting deployment are institutional and related to the utility operation. These issues are discussed further in Section 4.

Maui's two projects are not as cost competitive in that the loss of tax credits or the use of conservative assumptions eliminates the wind project and the biomass project becomes only marginally cost competitive. Optimistic assumptions increase the total number of viable projects to four, for a total generation of 617 million kWh annually.

On Oahu, no projects appear to be viable in the immediate future unless other factors are considered. For example, a wind project at Kahuku may be less expensive than projected because the infrastructure already exists.

On Kauai, only two projects appear to be cost competitive and only if optimistic assumptions are made. Given this result and the present over-capacity situation on Kauai, no large utility-scale projects are likely to be undertaken in the near future. Note that these projects are more feasible than previously thought and continuing investigations are warranted.

Small-scale renewable energy projects based on wind and solar technologies may turn out to be cost-effective on a distributed basis on Kauai and the other Hawaiian islands. This issue is addressed in Section 5.

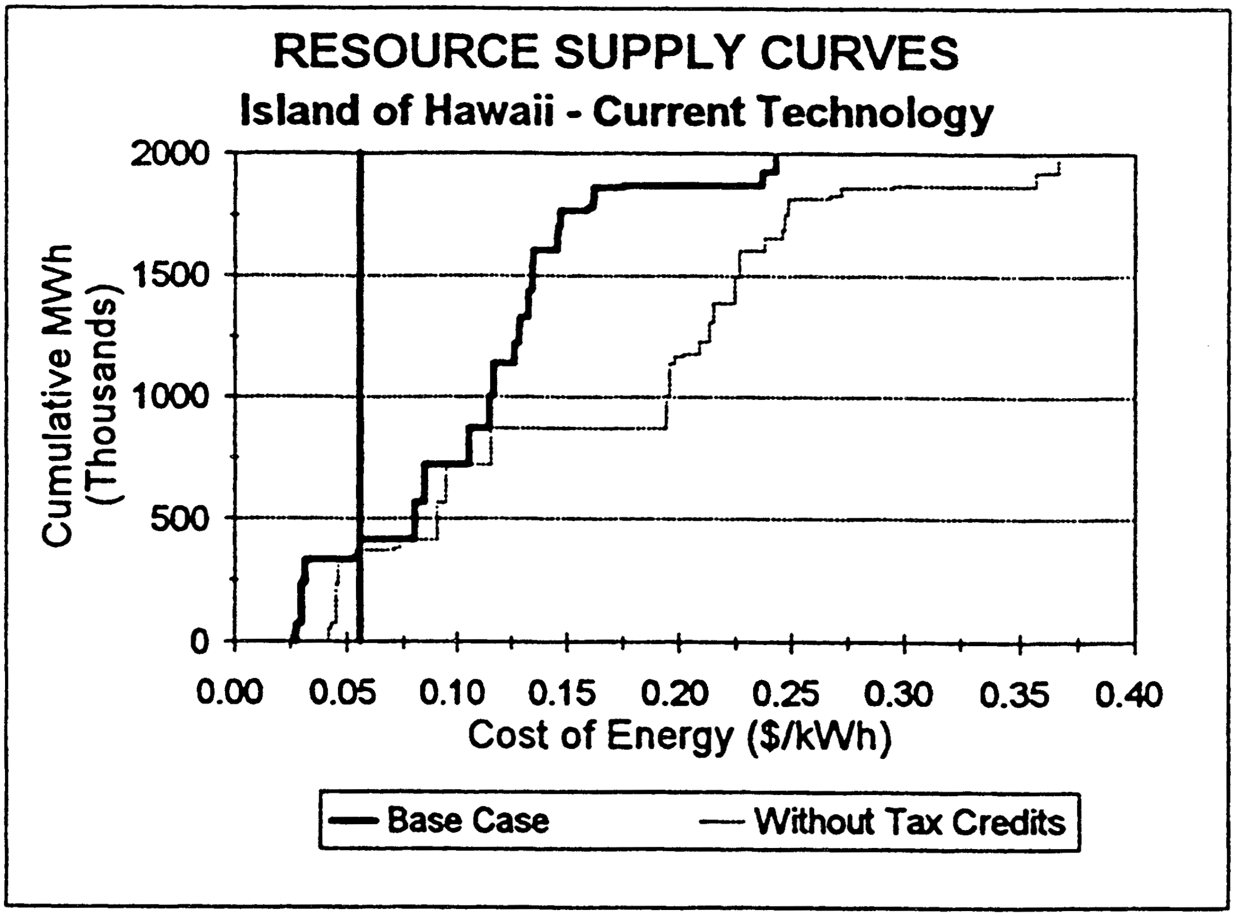


Figure 2-7. Sensitivity Analysis, Tax Credits

Statewide, the only technologies that are economic in 1995 are wind, biomass electric, and hydro. Examination of the resource supply curves reveals that the other technologies considered in this project (solar thermal, photovoltaic, wave, geothermal, and ocean thermal) are not viable options in the immediate future. Some of these technologies look promising by 2005, as discussed in Section 3.

Table 2-1. Summary of Potential Benefits, 1995

1995 — **Valuation: Constant Dollars** — **1995 Projected Utility Sales**

Tax Credits: Included — **Financing: Utility** — **Hawaii 957.0 GWh**

Data: Viable Projects — **Transmission Costs: Included** — **Maui 881.0 GWh**

Kauai 398.7 GWh

Renewable Energy Project					Optimistic			Nominal			Conservative		
Island	**Technology**	**Type**	**Location**	**MW**	**Annual MWh**	**Annual Benefit**	**% of Util. Sales**	**Annual MWh**	**Annual Benefit**	**% of Util. Sales**	**Annual MWh**	**Annual Benefit**	**% of Util. Sales**
Hawaii	Hydro		Umauma Stream	13.8	41,019	$140,770	4.3%						
	Wind		Kahua Ranch	5	12,334	$175,709	1.3%	10,516	$30,315	1.1%			
	Wind		Kahua Ranch	15	35,735	$439,508	3.7%						
	Wind		Lalamilo Wells	3	12,109	$389,297	1.3%	10,366	$263,836	1.1%	8,750	$133,310	0.9%
	Wind		Lalamilo Wells	30	108,832	$3,405,760	11.4%	92,510	$2,272,534	9.7%	77,474	$1,113,879	8.1%
	Wind		Lalamilo Wells	50	181,386	$5,866,563	19.0%	154,183	$3,988,439	16.1%	129,123	$2,069,816	13.5%
	Wind		N. Kohala	5	21,693	$729,458	2.3%	18,569	$510,089	1.9%	15,676	$282,460	1.6%
	Wind		N. Kohala	15	66,183	$2,263,502	6.9%	56,905	$1,615,269	5.9%	48,105	$944,383	5.0%
Maui	Biomass Elec	org waste	Puunene	25	168,630	$7,480,431	19.1%	153,300	$3,791,131	17.4%	137,970	$101,831	15.7%
	Biomass Elec	tree crops	Paia-Puunene	50	337,260	$2,344,907	38.3%						
	Wind		McGregor Point	10	23,189	$453,811	2.6%	19,874	$176,450	2.3%			
	Wind		NW Haleakala	10	19,980	$224,193	2.3%						
	Wind		NW Haleakala	30	52,801	$140,771	6.0%						
	Wind		NW Haleakala	50	88,001	$424,815	10.0%						
Oahu			***No projects were viable for 1995 cost scenario.***										
Kauai	Wind		Port Allen	5	9,111	$16,524	2.3%						
	Wind		N. Hanapepe	10	21,296	$188,922	5.3%						

SECTION 3. RESULTS OF THE RESOURCE SUPPLY CURVE MODEL FOR 2005

This section of the report discusses the renewable energy projects that appear to be economically and technically feasible for installation in 2005. These projects represent viable opportunities for the State of Hawaii and should be considered in the planning processes of both the government and the utilities. Although the analyses were conducted for the year 2005, many of these projects will be economically cost competitive before that date. Therefore, the results of this analysis can be immediately utilized by decision makers in Hawaii's energy community. The information should provide valuable insight into the potential energy options for the future and assist in guiding long-range planning activities.

There are a significant number of potential renewable energy projects and technologies that become viable generating options by 2005. However, examination and evaluation of renewable energy projects in 2005 involves less certainty than for the year 1995. Although costs are lower for all the technologies, the ranges over which they could vary are significantly greater in the future. In addition, factors such as economic conditions, fuel costs, utility demand, and legislative changes are more difficult to estimate with a high confidence level. Despite this uncertainty, the analyses for 2005 are based on a realistic set of assumptions regarding future conditions and the results are consistent with industry expectations. Whenever possible, a conservative approach was taken in analyzing the data. As conditions change, the RSC model can be used to update the analyses appropriately.

ANALYSIS APPROACH

The results for 2005 were analyzed in a manner similar to the analysis for 1995. The range between the conservative, nominal, and optimistic scenarios is larger for projects in 2005, and therefore the results cover a broader range of possible development scenarios. In addition, several technologies that were considered to be unavailable in 1995 are included in the 2005 analysis.

As with the 1995 projects, utility financing was assumed for all 2005 projects. Because the federal tax production incentives for wind and biomass are scheduled to expire for projects installed after 1999, these tax credits were not included in the analyses in this section. The state and federal investment tax credits were included. Although it is possible that additional tax credits will be put in place, removing the production tax credits for biomass and wind result in a conservative estimate of the renewable energy contribution. The base case analyses also include all required transmission costs to support the projects under consideration and constant dollars are assumed.

The avoided energy cost estimates for 2005 were based on escalating the 1995 avoided energy costs by 5% annually. This escalation is intended to represent projected increases in fuel or other operating costs. Although the choice of escalation rate can significantly affect the 2005 results, a 5% escalation is considered to be reasonable. A discussion of the sensitivity of the avoided cost assumptions is included in this section. As with the 1995 analyses, a vertical line representing this avoided cost was generated on the resource supply curve graphs for each island and each scenario that was evaluated. Projects to the left of this line on the RSC graphs represent projects that can be implemented at a levelized cost of energy that is lower than the projected cost for the utility to supply the same amount of energy in 2005. Projects to the right of the line are more expensive than the utility's avoided cost.

Note that as less expensive renewable energy projects are incorporated into the generation mix, the avoided cost will go down if the utility owns the project. If an independent power producer develops the project, the project's impact on avoided energy cost will depend on the terms of the power purchase contract with the utility. In actuality, avoided cost is an inappropriate measure to evaluate projects in

2005 because the structure under which it has been calculated will not be valid in 2005 if renewable energy projects are incorporated in any significant quantity. Because of this uncertainty, the avoided cost estimate used in this analysis for each island is not meaningful as an absolute number. It is important only in its use as a measure by which to compare existing generation options and utility practices to the renewable energy generation options that could be implemented in the future.

In the sections below, the 2005 results are summarized for each island in terms of the amount of electricity that could be generated and the annual cost savings realized from implementing each of the viable projects. Because so many projects on each island appear to be viable in 2005, the annual cost savings are discussed in terms of individual projects rather than in terms of the entire group. The entire group of projects presented for each island is, in most cases, greater than could be installed, therefore, a sum of the cost savings is not as meaningful as it was for 1995 projects. Given that more opportunity for cost-effective renewable energy project development exists than can be developed, the number and size of the renewable energy projects that are ultimately installed will be determined based on factors other than cost. These factors include penetration limits for intermittent resources, load growth, or competing land uses and are discussed in the next section.

Results are provided for each development scenario by island. The impact of varying the assumptions is also evaluated. The 2005 results are further analyzed in Section 4 to develop a realistic renewable energy implementation goal.

2005 RESULTS FOR THE ISLAND OF HAWAII

Resource supply curves for the base case, conservative and optimistic scenarios which list all the projects on Hawaii and their calculated cost of energy are included in Appendix A.

BASE CASE

Figure 3-1 shows the base case 2005 resource supply curve for the island of Hawaii. For this analysis, the avoided cost for HELCO was projected to be $0.0906/kWh in 2005. As shown in the graph, there are eleven renewable energy projects on Hawaii that could be implemented by 2005 at a more economical cost than the projected utility avoided cost. These projects include 3 wind projects, 1 geothermal project, 1 hydro project, 2 biomass electric projects utilizing tree crops and/or organic waste as the fuel source, 2 solar thermal dish projects, and 2 photovoltaic projects.

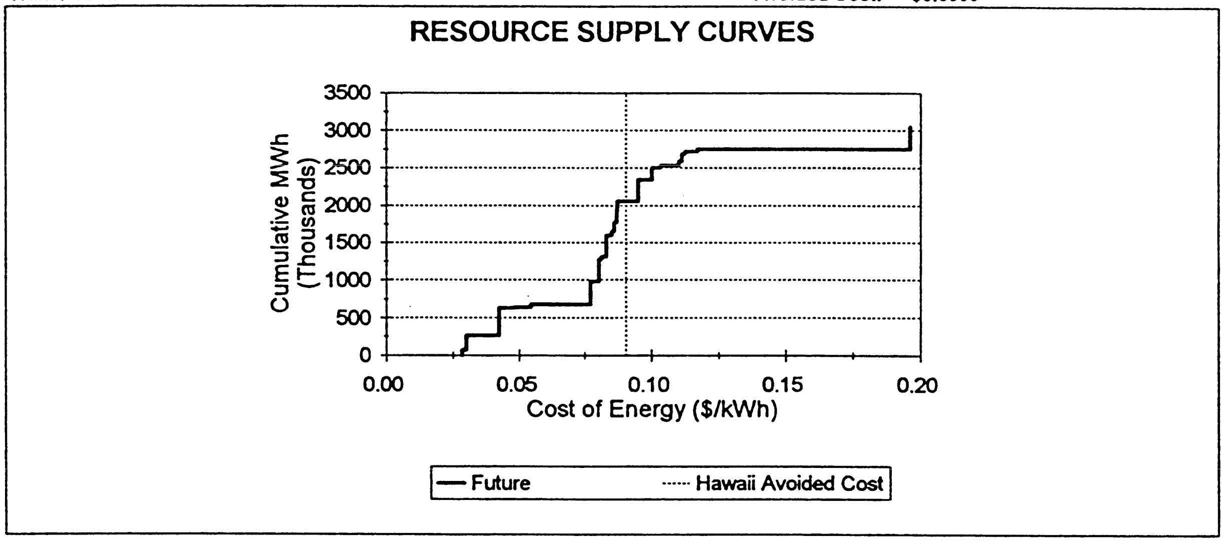
Although the graph shows only the most cost-effective project size, other project sizes are also viable at most of these sites under the nominal assumptions.

OPTIMISTIC AND CONSERVATIVE CASES

Under the optimistic assumptions in the model, five additional projects on Hawaii were determined to be cost competitive. These projects include a biomass project utilizing grass crops as the fuel source, a photovoltaic project at North Kohala, and three wave energy projects along the northern coast of the island. The North Kohala project site is one of the few sites in the state that has both solar and wind energy potential. Three of the fifteen projects identified as being viable under optimistic conditions are located at this site: one solar thermal project, one photovoltaic project, and one wind project. Development of one of these projects is likely to exclude development of the other two projects. The project and technology that is most likely to be developed will depend on a number of factors. The wind energy project is likely to be cost effective at an earlier date and the anticipated wind loads on solar technology equipment may cause a problem for the solar designs (high wind loads can affect performance). On the other hand, utility grid stability (wind may be more intermittent than solar at this site) or public acceptance could result in development opportunities for the solar technologies.

Under conservative assumptions, only three wind projects and one hydroelectric project are still viable. These projects are the same projects that were determined to be cost effective in 1995 under the optimistic scenarios. This result implies that these projects are likely to become viable earlier than 2005. It also indicates that the costs are better defined for these technologies than for the other, less mature technologies. The higher confidence level in the costs results from the fact that numerous wind and hydroelectric facilities have been commercially developed at other locations.

Island(s):	Hawaii	**Valuation:**	Constant Dollars
Technology:	All_Tech	**Financing:**	Utility
Certainty:	Nominal	**Tax Credits:**	Included
Stage:	Future Technology	**Data:**	Unique Location Lowest COE
Trans. Cost:	Cost Included	**Avoided Cost:**	$0.0906



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	MWh	COE
Wind		Hawaii	North Kohala	Future	Incl	Nominal	15	71,178	0.0288
Wind		Hawaii	Lalamilo Wells	Future	Incl	Nominal	50	192,086	0.0304
Geothermal		Hawaii	Kilauea	Future	Incl	Nominal	50	362,314	0.0425
Wind		Hawaii	Kahua Ranch	Future	Incl	Nominal	5	12,628	0.0480
Hydro		Hawaii	Umauma Stream	Future	Incl	Nominal	13.8	40,199	0.0544
Biomass Elec	tree & org waste	Hawaii	Hilo Coast	Future	Incl	Nominal	50	306,600	0.0772
Solar Thermal	dish	Hawaii	N. Kohala	Future	Incl	Nominal	15	29,416	0.0814
Solar Thermal	dish	Hawaii	Keahole	Future	Incl	Nominal	30	55,125	0.0852
Photovoltaic	tracking	Hawaii	Keahole	Future	Incl	Nominal	50	124,319	0.0862
Biomass Elec	tree crops	Hawaii	Hamakua Coast	Future	Incl	Nominal	25	153,300	0.0870
Photovoltaic	tracking	Hawaii	Waikoloa	Future	Incl	Nominal	50	124,319	0.0873
				Energy Produced below Avoided Cost				1,471,484	
				Annual Savings Potential from Renewables				$41,558,949	

Figure 3-1. 2005 Base Case Resource Supply Curve, Island of Hawaii

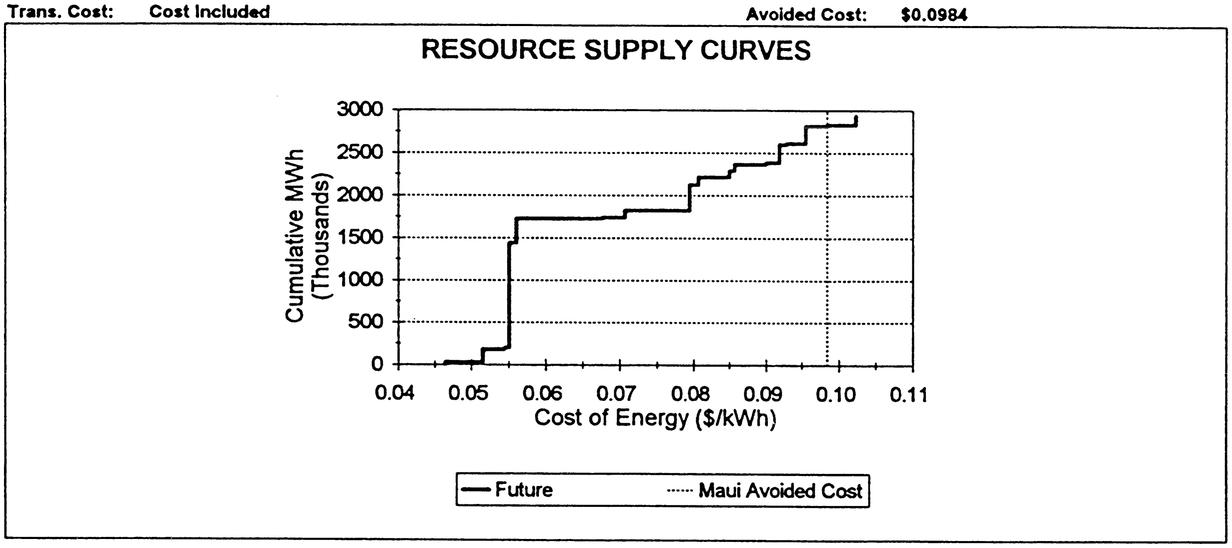
2005 RESULTS FOR THE ISLAND OF MAUI

Resource supply curves for the base case, conservative and optimistic scenarios which list all the projects on Maui and their calculated cost of energy are included in Appendix B.

BASE CASE

Figure 3-2 shows the base case resource supply curve of the island of Maui. For this analysis, the avoided cost for MECO was projected to be $0.0984/kWh in 2005. As shown in the graph, there are 13 renewable energy projects on Maui that could be implemented by 2005 at a more economical cost than the projected utility avoided cost. These projects include four wind projects, two biomass electric projects utilizing tree crops and/or organic waste as the fuel source, two solar thermal dish projects, three photovoltaic projects, and two wave energy projects.

Island(s):	**Maui**	**Valuation:**	**Constant Dollars**
Technology:	**All_Tech**	**Financing:**	**Utility**
Certainty:	**Nominal**	**Tax Credits:**	**Included**
Stage:	**Future Technology**	**Data:**	**Unique Location Lowest COE**
Trans. Cost:	**Cost Included**	**Avoided Cost:**	**$0.0984**



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	MWh	COE
Wind		Maui	McGregor Point	Future	Incl	Nominal	10	24,611	0.0465
Biomass Elec	org waste	Maui	Puunene	Future	Incl	Nominal	25	153,300	0.0515
Wind		Maui	NW Haleakala	Future	Incl	Nominal	10	21,205	0.0545
Wind		Maui	Puunene	Future	Incl	Nominal	10	15,784	0.0677
Wind		Maui	West Maui	Future	Incl	Nominal	50	77,546	0.0707
Biomass Elec	tree crops	Maui	Paia-Puunene	Future	Incl	Nominal	50	306,600	0.0795
Photovoltaic	tracking	Maui	Kahului	Future	Incl	Nominal	30	82,893	0.0807
Photovoltaic	tracking	Maui	Puunene	Future	Incl	Nominal	30	77,792	0.0850
Photovoltaic	tracking	Maui	Kihei	Future	Incl	Nominal	30	78,159	0.0857
Solar Thermal	dish	Maui	Puunene	Future	Incl	Nominal	10	16,430	0.0901
Wave		Maui	Opana Point	Future	Incl	Nominal	60	211,984	0.0920
Solar Thermal	dish	Maui	Kihei	Future	Incl	Nominal	10	16,922	0.0929
Wave		Maui	Lower Paia	Future	Incl	Nominal	60	203,974	0.0956
				Energy Produced below Avoided Cost				1,287,200	
				Annual Savings Potential from Renewables				$23,487,236	

Figure 3-2. 2005 Base Case Resource Supply Curve, Island of Maui

Although the graph shows only the most cost-effective project size, other project sizes are also viable at most of these sites.

OPTIMISTIC AND CONSERVATIVE CASES

Under the optimistic assumptions in the model, one additional wave project and one additional solar thermal dish project are shown to be viable. Smaller-sized projects at sites already included in the nominal scenario also become viable options.

Under conservative assumptions, the four wind projects (in all sizes) and a single biomass electric project using organic waste as a fuel source are the only cost-competitive options. These results include one more wind project than was viable under the optimistic scenario in 1995. Biomass electric using tree crops as a fuel source, photovoltaic, and solar thermal projects are all within 10% of being cost competitive under the conservative scenario.

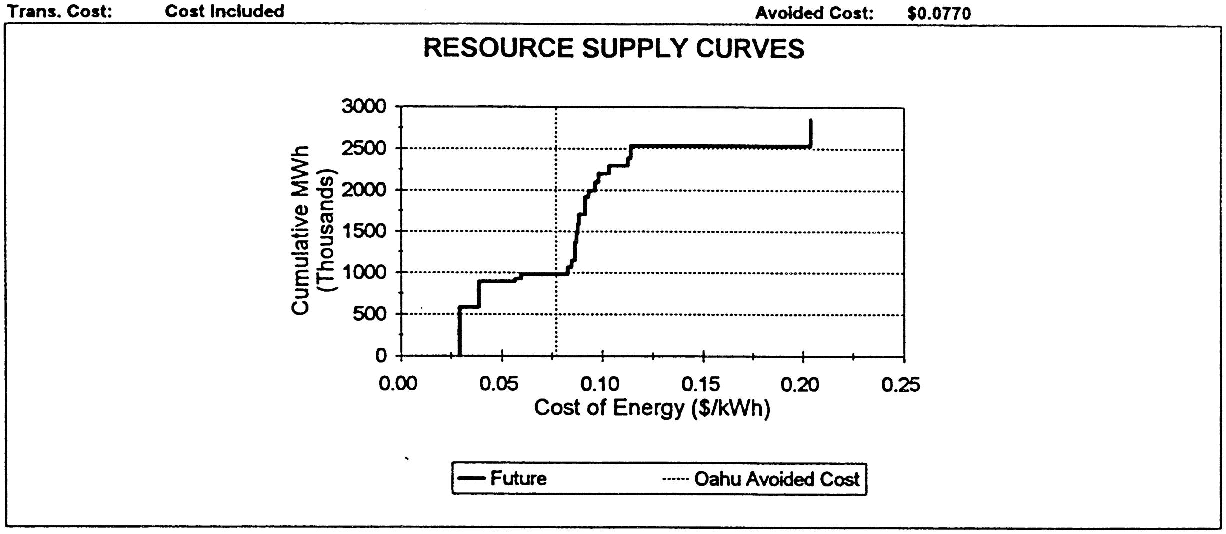
2005 RESULTS FOR THE ISLAND OF OAHU

Resource supply curves for the base case, conservative and optimistic scenarios which list all the projects on Oahu and their calculated cost of energy are included in Appendix C.

BASE CASE

Figure 3-3 shows the base case resource supply curve of the island of Oahu. For this analysis, the avoided cost for HECO was projected to be $0.077/kWh in 2005.

Island(s):	Oahu	Valuation:	Constant Dollars
Technology:	All_Tech	Financing:	Utility
Certainty:	Nominal	Tax Credits:	Included
Stage:	Future Technology	Data:	Unique Location Lowest COE
Trans. Cost:	Cost Included	Avoided Cost:	$0.0770



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	MWh	COE
Biomass Elec	org waste	Oahu	Barber's Point	Future	Incl	Nominal	50	306,600	0.038
Wind		Oahu	Kaena Point	Future	Incl	Nominal	15	31,558	0.05
Wind		Oahu	Kahuku	Future	Incl	Nominal	30	56,977	0.059
				Energy Produced below Avoided Cost				395,135	
				Annual Savings Potential from Renewables				$13,307,378	

Figure 3-3. 2005 Base Case Resource Supply Curve, Island of Oahu

As shown in the graph, there are two wind projects and one biomass electric project using organic waste as a fuel source that could be implemented by 2005 at a more economical cost than the projected utility avoided cost. The wind projects include Kaena Point (at either 2 or 15 MW) and Kahuku (at either 30, 50, or 80 MW). Although all three size projects at Kahuku are viable options, the 30 MW project has the lowest cost of energy due to the cost of the transmission upgrade requirement. A 50 MW solar thermal dish project at Pearl Harbor is approximately 7% more expensive than the projected utility avoided cost.

OPTIMISTIC AND CONSERVATIVE CASES

Under the optimistic assumptions in the model, 15 projects appear to be viable. In addition to the base case project, 6 wave projects, 3 photovoltaic projects, 2 solar thermal projects, and 1 biomass electric project using grass crops as a fuel appear to be viable. The large number of wave projects and wave energy's cost effectiveness on Oahu (lowest cost of energy following the organic waste and wind energy projects) illustrate that wave energy offers significant contribution potential if the technology matures as expected under optimistic assumptions. A strong wave resource is available on the northeast coast of Oahu. Additional research on this technology and demonstration projects are needed to validate the cost and performance estimates.

All three viable projects identified in the base case remain viable under conservative assumptions. None of these projects were considered to be viable in 1995.

2005 RESULTS FOR THE ISLAND OF KAUAI

Resource supply curves for the base case, conservative and optimistic scenarios which list all the projects on Kauai and their calculated cost of energy are included in Appendix D.

BASE CASE

Figure 3-4 shows the base case resource supply curve of the island of Kauai. For this analysis, the avoided cost for KECO was projected to be $0.0919/kWh in 2005. As shown in the graph, there are two wind projects, one hydroelectric, one solar thermal dish, and two biomass electric projects (one tree crops combined with one tree crop and organic waste) that could be implemented by 2005 at a more economical cost than the projected utility avoided cost. Additional biomass projects are within 5% of the projected avoided cost.

OPTIMISTIC AND CONSERVATIVE CASES

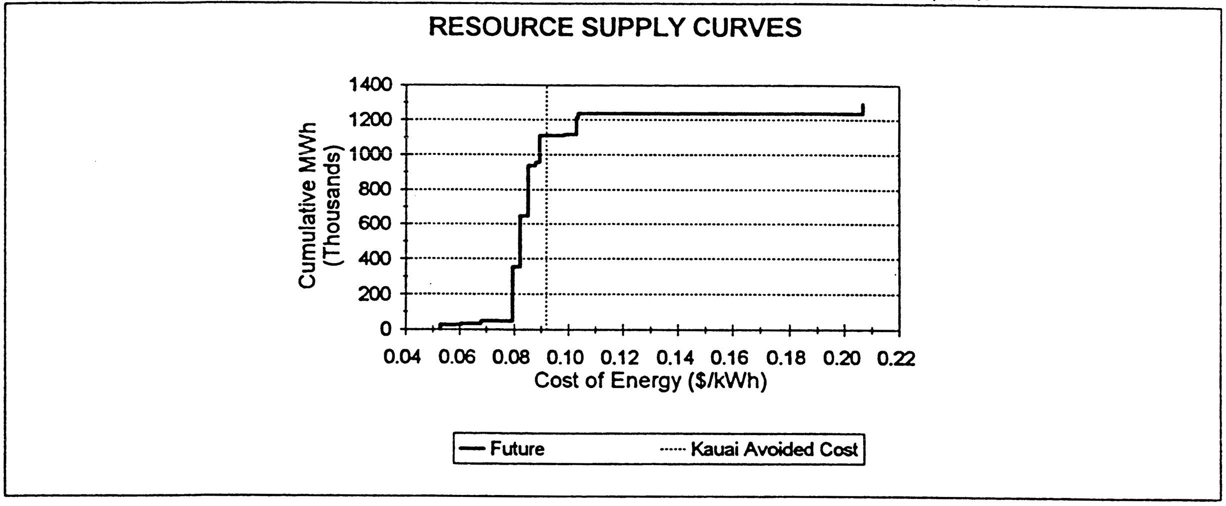
Under the optimistic assumptions in the model, nine projects appear to be viable. In addition to the base case projects, one wind project, one wave project, one photovoltaic project, and one solar thermal dish project become cost-effective under optimistic assumptions.

Under conservative assumptions, only the two wind projects and the hydroelectric project in the base case are still viable. The next most cost-effective project is approximately 15% more expensive than the projected avoided cost. This result again demonstrates the uncertainty associated with the developing technologies.

IMPACTS OF VARYING ASSUMPTIONS

The impacts of varying the assumptions for financing, the inclusion of transmission costs, and the consideration of tax credits are essentially the same as the impacts discussed in Section 2. Whether the project is utility financed or privately financed slightly increases the costs but does not cause viable projects to move to the right of the avoided cost line on the resource supply curves. The exclusion of transmission costs affects the same projects in the 2005 results as it did in the 1995 results.

Island(s):	Kauai	**Valuation:**	Constant Dollars
Technology:	All_Tech	**Financing:**	Utility
Certainty:	Nominal	**Tax Credits:**	Included
Stage:	Future Technology	**Data:**	Unique Location Lowest COE
Trans. Cost:	Cost Included	**Avoided Cost:**	$0.0919



Technology	Type	Island	Location	Stage	Trans$	Certainty	MW	MWh	COE
Wind		Kauai	N. Hanapepe	Future	Incl	Nominal	10	22,602	0.0529
Wind		Kauai	Port Allen	Future	Incl	Nominal	5	9,321	0.0603
Hydro		Kauai	Wailua River	Future	Incl	Nominal	6.6	16,435	0.0678
Biomass Elec	tree & org waste	Kauai	Kaumakani	Future	Incl	Nominal	50	306,600	0.0794
Solar Thermal	dish	Kauai	Barking Sands	Future	Incl	Nominal	10	17,250	0.0878
Biomass Elec	tree crops	Kauai	Lihue	Future	Incl	Nominal	25	153,300	0.0894
				Energy Produced below Avoided Cost				525,508	
				Annual Savings Potential from Renewables				$5,870,070	

Figure 3-4. 2005 Base Case Resource Supply Curve, Island of Kauai

As in 1995, the exclusion of tax credits has the greatest impact on the 2005 results. The effects of removing the tax credit considerations in the sensitivity analysis are not as large for biomass and wind projects because the production tax incentives are not included for the 2005 analysis. For solar projects, however, removing tax credits from consideration has a significant impact on their viability.

SENSITIVITY OF RESULTS TO AVOIDED COST ASSUMPTIONS

Visual examination of any of the resource supply curves quickly reveals the extent to which higher or lower avoided cost assumptions will affect the set of cost-competitive project choices. The impact of moving the vertical avoided cost line to the right (for higher avoided cost) or left (for lower avoided cost) can be easily seen on the graphs. The steeper the curve, the more sensitive the results are to the avoided cost assumptions.

On Hawaii, the flatness of the nominal RSC graph at the avoided-cost line intersection point illustrates that relatively small changes in the avoided cost assumptions will not affect the number of viable projects. On Oahu, however, the avoided cost line crosses the nominal RSC curve at a fairly steep part of the curve. Oahu results, therefore, are more sensitive to the avoided cost assumptions.

2005 RESULTS FOR BIOMASS FUELS

The RSC model also includes cost-of-energy estimates for a number of biomass fuel projects in 2005. Although these projects are not discussed in detail in this report, they also represent viable opportunities to use renewable resources to reduce the state's petroleum dependency. In the RSC model, the cost of energy for biomass fuel projects was converted into cents/kWh based on the heat content of the fuels to allow for comparison to electricity generating projects. In actual practice, these biomass projects will produce liquid fuels, not electricity, and will be competing for markets now dominated by gasoline. To evaluate whether these projects are economically viable options for the future, a more appropriate comparison can be made between the competing fuel alternatives.

Table 3-1 shows the estimated cost of the biomass fuels on a $/gallon basis for each of the projects contained in the RSC database. Estimates are provided for the optimistic, nominal, and conservative scenarios for both methanol and ethanol production projects. Note that these fuels have a different energy conversion efficiency from other fuel alternatives so a direct comparison of the costs presented in Table 3-1 to gasoline prices, for example, is not appropriate. It is also important to note that the published price (or pump price) of alternative fuels often includes hidden costs such as taxes and transportation. Although it is beyond the scope of this project to evaluate the costs of other fuel alternatives in detail, a few conclusions can be drawn regarding these energy conversion technologies.

Table 3-1. Cost Summary of Biomass Fuels

				Cost per Gallon*		
Island	**Type**	**Location**	**MW**	**Optimistic**	**Nominal**	**Conservative**
Hawaii	tree crops-methanol	Hamakua Coast	47	0.97	1.34	1.78
Hawaii	tree crops-methanol	Hilo Coast	47	1.00	1.38	1.84
Hawaii	grass crops-methanol	Kaumakai	47	1.15	1.58	2.10
Kauai	tree crops-methanol	Lihue	47	0.99	1.37	1.82
Kauai	tree crops-methanol	Kaumakani	47	1.03	1.42	1.89
Maui	org waste-methanol	Puunene	47	0.58	0.93	1.35
Maui	tree crops-methanol	Paia-Puunene	95	0.70	0.97	1.29
Maui	grass crops-methanol	Paia-Puunene	95	0.82	1.12	1.49
Maui	grass crop-ethanol	Paia-Puunene	141	1.42	1.95	2.60
Maui	tree crop-ethanol	Paia-Puunene	70	1.68	2.31	3.08
Oahu	org waste-methanol	Barbers Point	95	0.25	0.49	0.79
Oahu	org waste-ethanol	Barbers Point	70	0.77	1.30	1.94

* MGPY converted to MW based on the following equations.
1 MW = 1,000 MW x 8,760 hr/yr / 16.61 kWh/gal MeOH / 1,000,000 gal = 0.5274 MGPY MeOH
1 MW = 1,000 MW x 8,760 hr/yr / 24.70 kWh/gal EtOH / 1,000,000 gal = 0.3547 MGPY EtOH

A recently completed report from DBEDT entitled *Ethanol Production in Hawaii* by Dr. Robert Shleser indicates that the competitive production price per gallon for ethanol varies considerably depending on the potential markets for fuel ethanol. Competitive production prices range from a low of approximately $0.60 to more than $2.00 per gallon. The 2005 results from the model show optimistic production prices for ethanol ranging from $0.77 (with organic waste as the fuel source) to $1.42 per gallon (with grass crops as the fuel source). For an ethanol production facility using tree crops as the fuel source, costs ranged from a conservative estimate of $3.08 to an optimistic estimate of $1.68 per gallon. Similar comparisons can be made for methanol production projects. Although these numbers are far from conclusive, they illustrate that biomass fuels are in a realistic cost range to warrant further analysis.

SUMMARY OF 2005 RESULTS

Several conclusions are apparent from an examination of the RSC model results for 2005. Tables 3-2 through 3-5 summarize the energy production and potential benefits or savings to the state for all of the viable renewable energy projects for each island and development scenario. It is evident by the number of projects that all of the renewable energy generation cannot be utilized by the state's utilities. The renewable energy integration plans presented in the Section 4 prioritize and summarize the projects based on their cost effectiveness and ability to be incorporated into the state's utility grids.

Even under the conservative scenario, cost-effective projects exist on each island. For Hawaii and Maui, the number of projects under all scenarios is significant, again indicating the large potential for renewable energy on these islands.

On Oahu, large-scale projects are cost competitive under nominal and conservative conditions for biomass and wind technologies. Even though these projects are larger than considered on the other islands, they make a fairly small contribution in terms of energy production due to the larger demand on Oahu. Nonetheless, the annual savings potential to the state is significant even when other benefits are not considered.

On Kauai, projects are viable under all scenarios. The nominal cases include a wide diversity of technologies including biomass, hydro, solar thermal, and wind.

Table 3-2. Summary of Potential Benefit on Hawaii, 2005

Table 3-3. Summary of Potential Benefit on Maui, 2005

Table 3-4. Summary of Potential Benefit on Oahu, 2005

2005 - Oahu | **Valuation: Constant Dollars** | **2005 Projected Utility Sales**
Tax Credits: Excluded | **Financing: Utility** | **8,550.9 GWh**
Data: Viable Projects | **Transmission Costs: Included**

Renewable Energy Project				Optimistic			Nominal			Conservative		
Technology	Type	Location	MW	Annual MWh	Annual Benefit	% of Util. Sales	Annual MWh	Annual Benefit	% of Util. Sales	Annual MWh	Annual Benefit	% of Util. Sales
Biomass Elec	org waste	Barber's Point	50	337,260	$19,415,948	3.9%	306,600	$11,677,840	3.6%	275,940	$3,939,732	3.2%
Photovoltaic	tracking	Lualualei	20	51,371	$3,932	0.6%						
Photovoltaic	tracking	Lualualei	50	128,426	$901,656	1.5%						
Photovoltaic	tracking	N. Ewa Plain	50	128,426	$795,581	1.5%						
Photovoltaic	tracking	Pearl Harbor	50	128,426	$846,393	1.5%						
Solar Thermal	dish	Lualualei	50	84,957	$299,260	1.0%						
Solar Thermal	dish	Pearl Harbor	50	89,197	$457,192	1.0%						
Wave		Kahuku Point	30	132,640	$3,588,223	1.6%						
Wave		Kahuku Point	60	265,253	$7,537,155	3.1%						
Wave		Makapuu	30	139,714	$4,074,677	1.6%						
Wave		Makapuu	60	279,377	$8,646,189	3.3%						
Wave		Mokapu Point	30	122,913	$2,734,842	1.4%						
Wave		NE Coast 2A	30	129,936	$3,368,929	1.5%						
Wave		NE Coast 2C	30	126,276	$3,098,195	1.5%						
Wave		Waimanalo Bay	30	111,677	$1,950,993	1.3%						
Wind		Kaena Point	2	4,673	$123,986	0.1%	4,002	$61,156	0.0%			
Wind		Kaena Point	15	36,966	$1,107,657	0.4%	31,558	$642,174	0.4%	26,560	$129,058	0.3%
Wind		Kahuku	30	67,029	$1,869,607	0.8%	56,977	$987,364	0.7%	$47,716	$17,197	0.6%
Wind		Kahuku	50	111,268	$3,019,081	1.3%	94,581	$1,564,323	1.1%			
Wind		Kahuku	80	178,298	$3,930,812	2.1%	151,558	$1,603,709	1.8%			

Table 3-5. Summary of Potential Benefit on Kauai, 2005

2005 - Kauai	**Valuation:** Constant Dollars	**2005 Projected Utility Sales**	
Tax Credits: Included	**Financing:** Utility	**568.3 GWh**	
Data: Viable Projects	**Trans. Cost:** Cost Included		

Renewable Energy Project				Optimistic			Nominal			Conservative		
Technology	Type	Location	MW	Annual MWh	Annual Benefit	% of Util. Sales	Annual MWh	Annual Benefit	% of Util. Sales	Annual MWh	Annual Benefit	% of Util. Sales
Biomass Elec	tree & org waste	Kaumakani	50	337,260	$12,069,774	59.3%	306,600	$3,838,465	53.9%			
Biomass Elec	tree crops	Lihue	25	168,630	$4,538,343	29.7%	153,300	$389,827	27.0%			
Hydro		Wailua River	6.6	16,770	$475,719	3.0%	16,435	$395,840	2.9%	16,267	$328,852	2.9%
Photovoltaic	tracking	Barking Sands	10	26,407	$240,253	4.6%						
Solar Thermal	dish	Barking Sands	10	18,112	$284,532	3.2%	17,250	$70,213	3.0%			
Wave		Anahola	10	41,417	$1,182,176	7.3%						
Wave		Anahola	30	124,296	$4,609,212	21.9%						
Wind		Anahola	7	9,618	$111,449	1.7%						
Wind		N. Hanapepe	10	26,372	$1,263,460	4.6%	22,602	$881,293	4.0%	19,107	$469,261	3.4%
Wind		Port Allen	5	10,940	$465,153	1.9%	9,321	$294,433	1.6%	7,828	$108,881	1.4%

SECTION 4. PROJECT IMPLEMENTATION ANALYSES FOR INTERMITTENT RENEWABLE ENERGY RESOURCES

In evaluating the renewable energy generating options, it is important to consider the value of the energy to a utility as well as the cost of generation. Utilities commonly consider intermittent generating resources, such as wind, solar, and wave energy, to be less valuable than firm generating resources because intermittent resources are non-dispatchable. The value of the resource to the utility has significant impacts on the likelihood of project implementation. If these intermittent resources can be shown to have some quantifiable value to the utility, the likelihood of implementation is increased.

The following sections provide summaries of analyses aimed at identifying the value of these intermittent resources. These analyses include utility load matching with renewable energy project output on a diurnal and seasonal basis, determination of capacity value, and a comparison of the impact of time-of-day delivery and pricing scenarios for each island. Renewable energy projects also have value in their environmental and societal benefits, reduced fuel risk, short lead time, and modularity. Although these attributes should be fully considered in any planning process, their quantification is beyond the scope of this study.

For each of the analyses and results presented below, typical outputs or representative projects are discussed for wind, solar, and wave energy technologies. The other technologies evaluated in this study are considered to be firm generating resources. A differentiation between solar thermal and photovoltaics is not generally made because the output from both types of projects is similar on a diurnal and seasonal basis.

UTILITY LOAD MATCHING

As part of Phase 3, RLA developed diurnal and seasonal energy estimates for all the intermittent renewable energy projects contained in the RSC database. Diurnal estimates were developed on both a monthly and annual basis. A user-friendly computer model (separate from the RSC model) was developed to allow for graphical presentation and analysis of this information. The program allows the user to choose a single project or a combination of projects to graph against the utility load curves for each island. If a combination of projects is chosen, the program sums the diurnal and or seasonal output from the different projects and graphs the combined output as a single line. This option allows the user to evaluate whether the combination of projects within an island provides a better load match than a single project.

Figures 4-1 to 4-3 are sample graphs from the utility load matching program for each technology on a diurnal and seasonal basis for the island of Hawaii. The basic shape of the utility load curve is similar on all the islands. Because there is a great number of possible graphing combinations, these graphs are provided as illustrative results only. This information provided the basis for conducting the capacity value and time-of-day analyses described below. In addition, a number of general conclusions can be drawn for each technology.

Figure 4-1 shows the diurnal and seasonal energy output patterns for a 30 MW solar thermal project at Waikoloa. The shape of the curves is similar for solar projects on each island regardless of the project size or solar technology utilized. As shown in the graphs, the shape of the seasonal curve follows the utility load curve fairly well. On a diurnal basis, however, the energy output from solar projects drops off before the utility system hits its daily peak load.

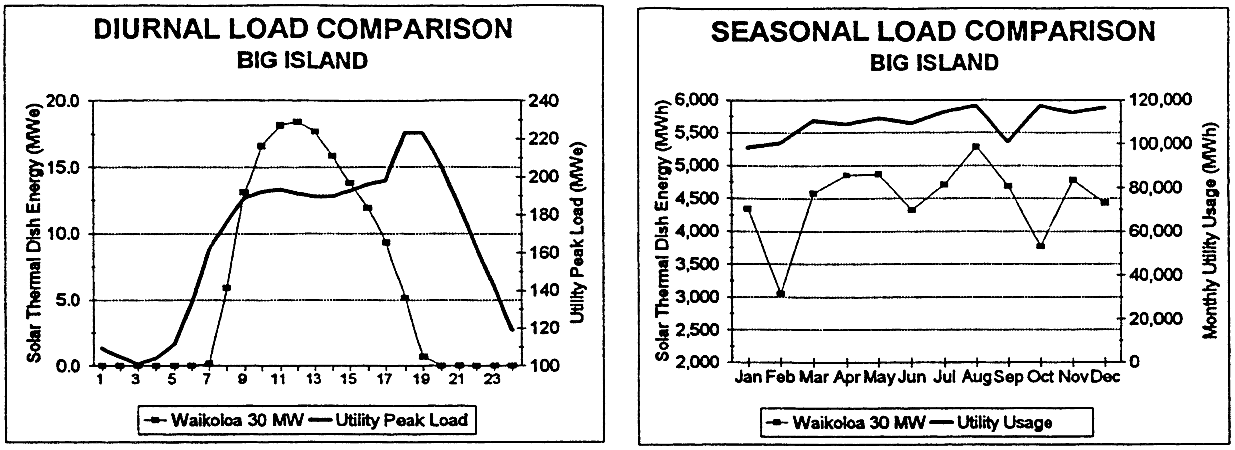


Figure 4-1. Diurnal and Seasonal Load Comparison, Solar

Figure 4-2 shows the diurnal and seasonal energy output patterns for a 30 MW wave energy project off the north Kohala coast. Again, the shape of these curves is similar for wave projects in other locations. Note, however, that high-quality wave resource data were not available to use as a basis for energy output estimates. Actual data from specific project sites may yield different results. As shown in the graphs, the shape of seasonal curve is not as well matched to the utility load as the solar curve. On a diurnal basis, the output from a wave project is variable and the shape of the curve is not particularly well matched to the utility load.

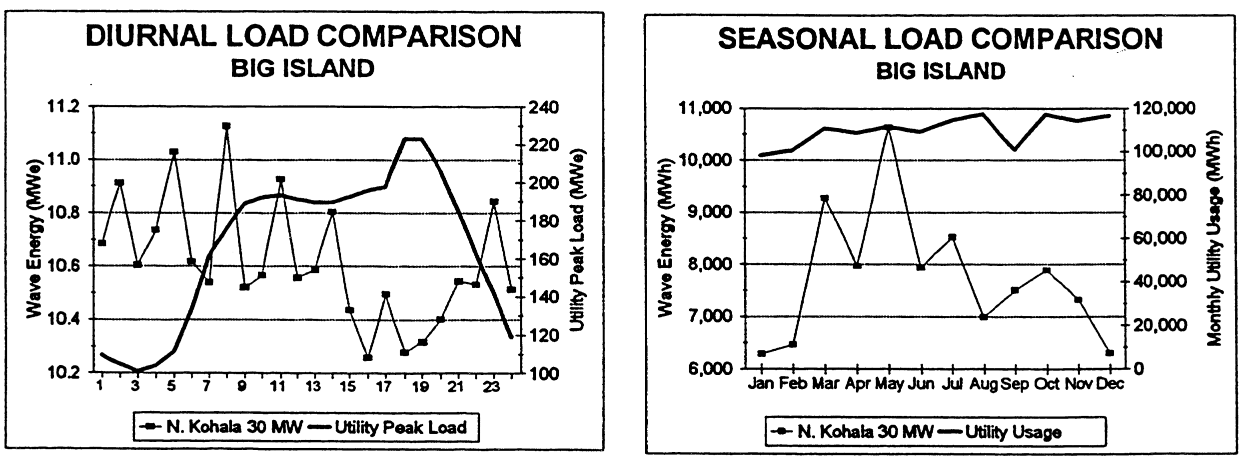


Figure 4-2. Diurnal and Seasonal Load Comparison, Wave

Figure 4-3 shows the diurnal and seasonal energy output patterns for three wind energy projects in different locations. Three graphs are shown to illustrate that the wind resource exhibits different seasonal and diurnal patterns in different project locations. In this example, the three sites – North Kohala, Lalamilo, and Kahua Ranch – are fairly close to each other. As shown in the graphs, the shape of the seasonal curves follows the utility load fairly well despite slight variations between projects. On a diurnal basis, the output of the three projects is significantly different. The North Kohala project exhibits the best match to the utility diurnal load; however, the Kahua Ranch project peaks at the same time as the utility system diurnal peak. Wind projects on other islands exhibit different diurnal patterns.

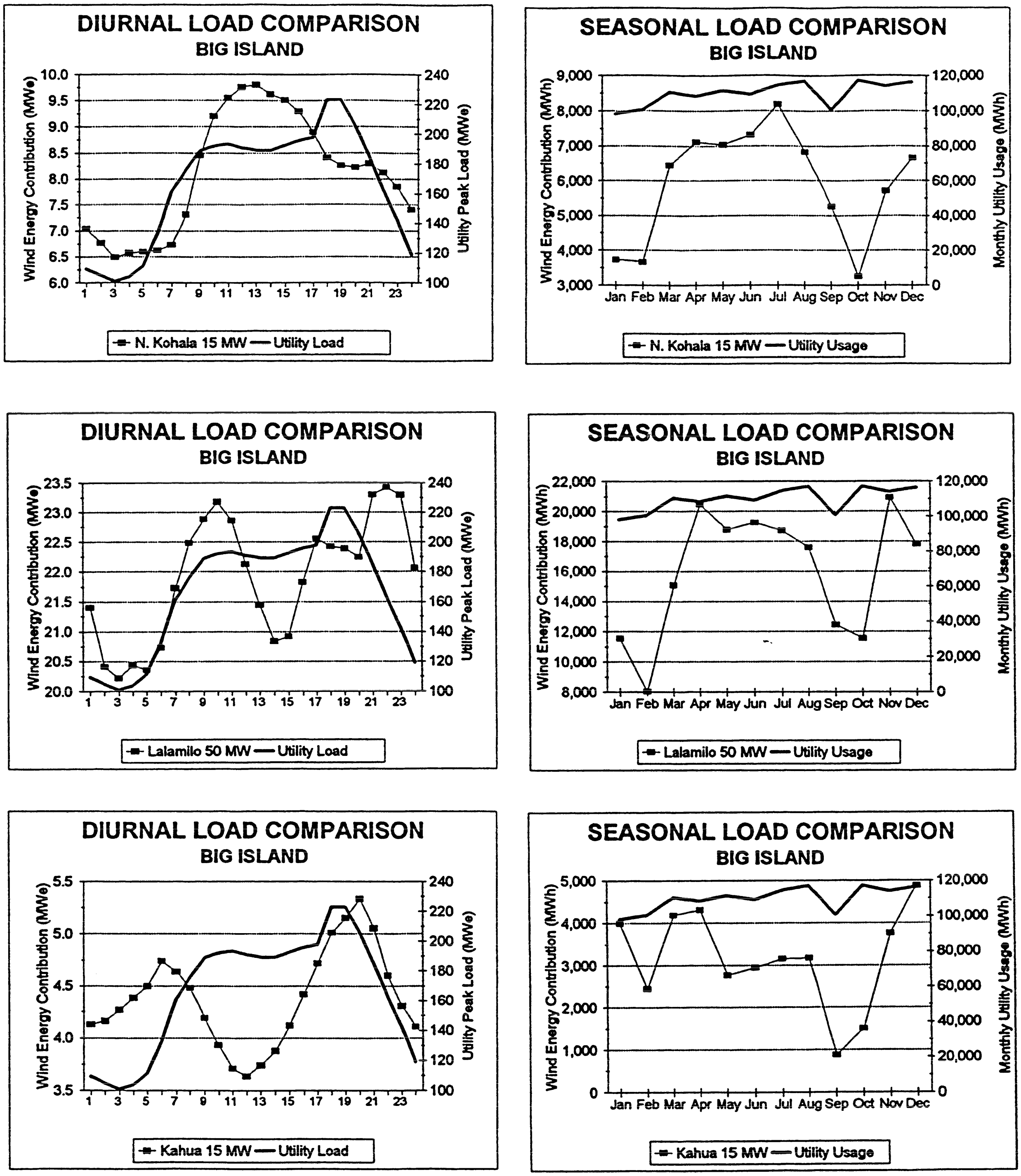


Figure 4-3. Diurnal and Seasonal Load Comparison, Wind

Because diurnal patterns can vary by season, diurnal estimates were developed for each month as well as on an annual basis. Figure 4-4 shows an example of how the diurnal pattern can vary by month at a typical wind project. Diurnal and seasonal outputs were not summarized for either biomass or ocean thermal projects because these project types are firm generating resources. It is possible to stockpile biomass fuel to generate energy only during periods of higher demand; however, this scenario would only be worthwhile if an economic incentive such as time-of-day payment rates was available.

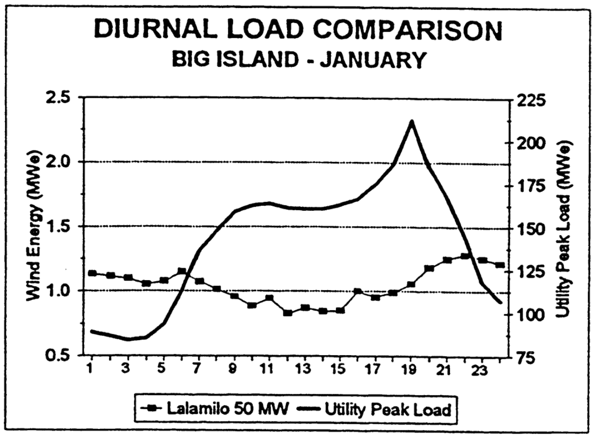
CAPACITY VALUE FOR INTERMITTENT RESOURCES

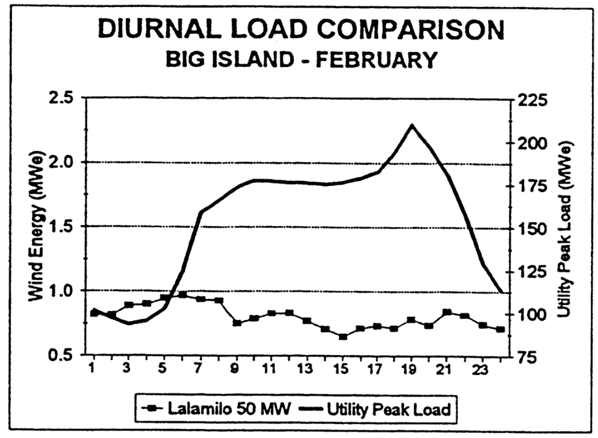
Electrical generating plants are generally characterized by both an energy value and a capacity value. For intermittent resources, characterizing the *energy* value to a utility is relatively straightforward and generally represents the savings due to fuel displacement and possibly O&M cost. The *capacity* value of intermittent resources, however, is more difficult to quantify.

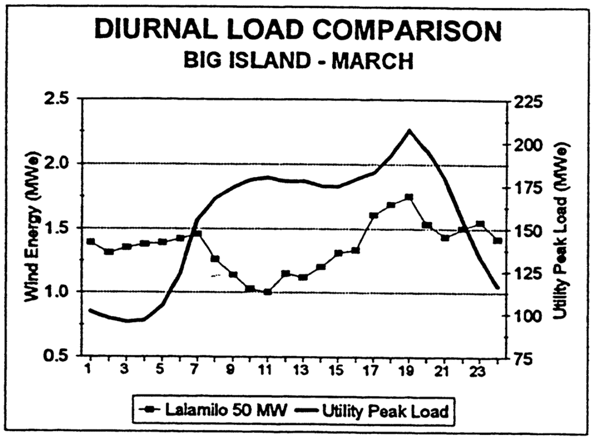
In the context of electric utility planning, capacity value refers to the ability of a generating resource to help meet peak loads. The capacity value depends on the quality and characteristics of the intermittent resource and on how well it complements the utility system under consideration. Capacity has value only if the addition of the resource to the system measurably increases the reliability of the system by reducing the probability that the system will fail to meet its peak loads. Practical experience with utilities in other locations (particularly with wind energy facilities) indicates that, in some cases, intermittent resources are able to defer the acquisition of other generating resources. Capacity value is extremely site-specific, however, and must be analyzed on a case-by-case basis.

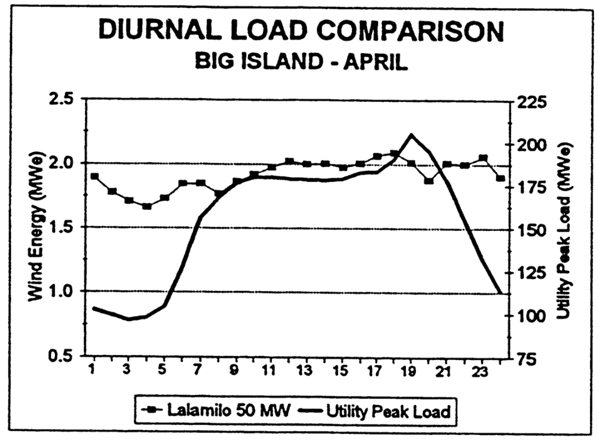
Although there are little actual data available, some studies have suggested that the average capacity factor may be a reasonable indicator of wind energy capacity at low penetrations levels. In certain situations, however, this simplistic approach may result in an overestimation of capacity value. More sophisticated methods employed by utilities include conducting loss-of-load probability (LOLP) calculations as the basis for estimating capacity. A LOLP analysis requires detailed information about the capacity and forced outage rates of each unit in the utility system as well as detailed information about the intermittent generation output and the system load. A base case analysis is run using current loads and resources, then the new resource under consideration is added to the system (for intermittent technologies, it is generally modeled with a high forced outage rate), and the LOLP for both analyses is compared to a reference value. An LOLP analysis requires significant effort and very detailed operating information and was therefore beyond the scope of this study.

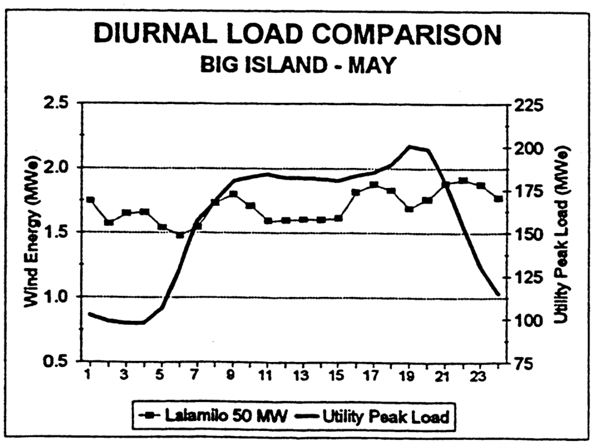
An intermediate approach to determining capacity value is to analyze the periods during which system loads are high and system marginal costs are likely to be correspondingly high. The underlying assumption with this approach is that capacity is acquired for its load carrying capability during periods of high loads. To analyze the capacity value of intermittent renewable energy projects in Hawaii, RLA examined the output from projects during periods of high hourly system loads. To conduct the analysis, the hourly system load values for the peak week in each month were summarized for each utility in Hawaii. The hourly output which corresponded to the peak system values was then calculated for each intermittent renewable energy project (based on actual resource data). The results of this analysis for a typical wind, solar, and wave energy project are summarized graphically in Figures 4-5 to 4-7. In the graphs, the peak load hours and corresponding renewable energy project output are sorted in descending order and graphed as two separate lines. The renewable energy project output is given as a percent of its rated capacity. The variability of the intermittent resources during the high-load periods is easily seen on the graphs.











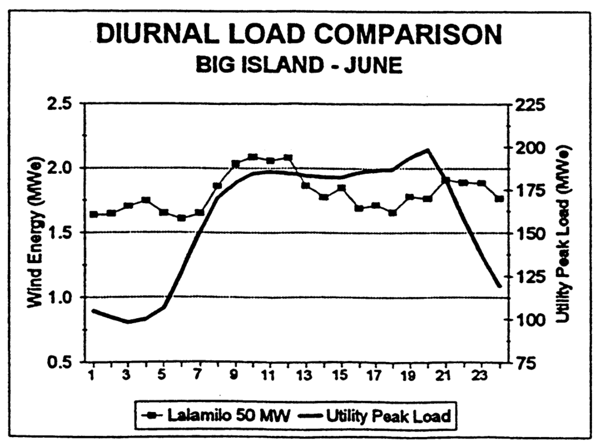


Figure 4-4. Monthly Diurnal Patterns, Wind

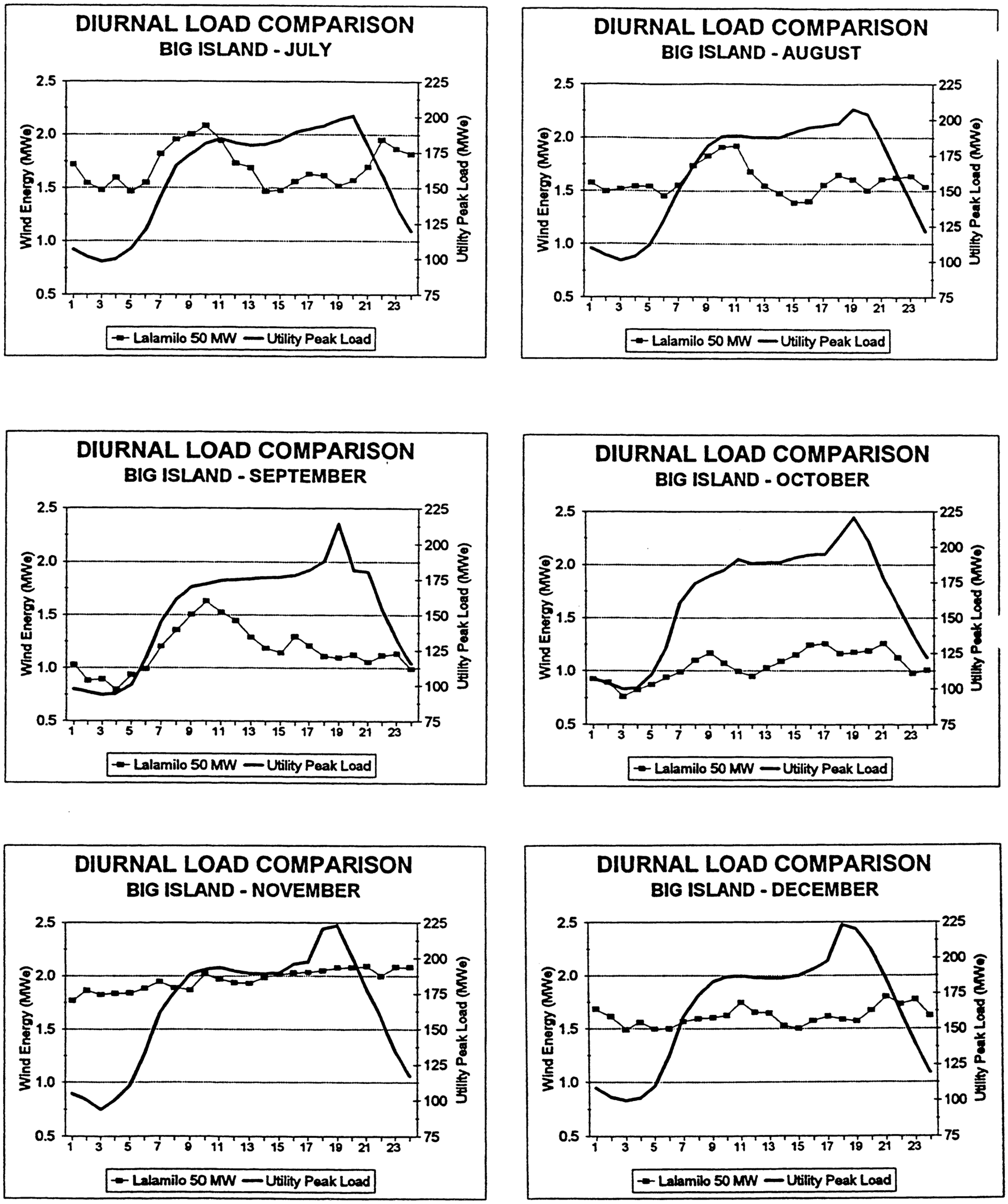


Figure 4-4. Monthly Diurnal Patterns, Wind (Continued)

As shown in Figure 4-5, a typical wind energy project produces between 10% and 50% of its rated capacity during the peak hours of the year. This result can be interpreted to indicate that, at a minimum, wind energy projects provide a 10% capacity value to the utility. If the average rated capacity during peak hours is used to estimate capacity value, the project shown in Figure 4-5 would have a capacity value of approximately 25%. As shown on Figure 4-6, a typical solar project produces between 0% and 70% of its rated capacity during peak hours. The 0% values occur during the early evening peaks when the solar resource is unavailable. As shown in Figure 4-7, a typical wave project produces between 30% and 60% of its rated capacity during peak hours. If capacity value is determined based on a project's minimum rated capacity during peak hours, wave projects have the greatest capacity value to a utility.

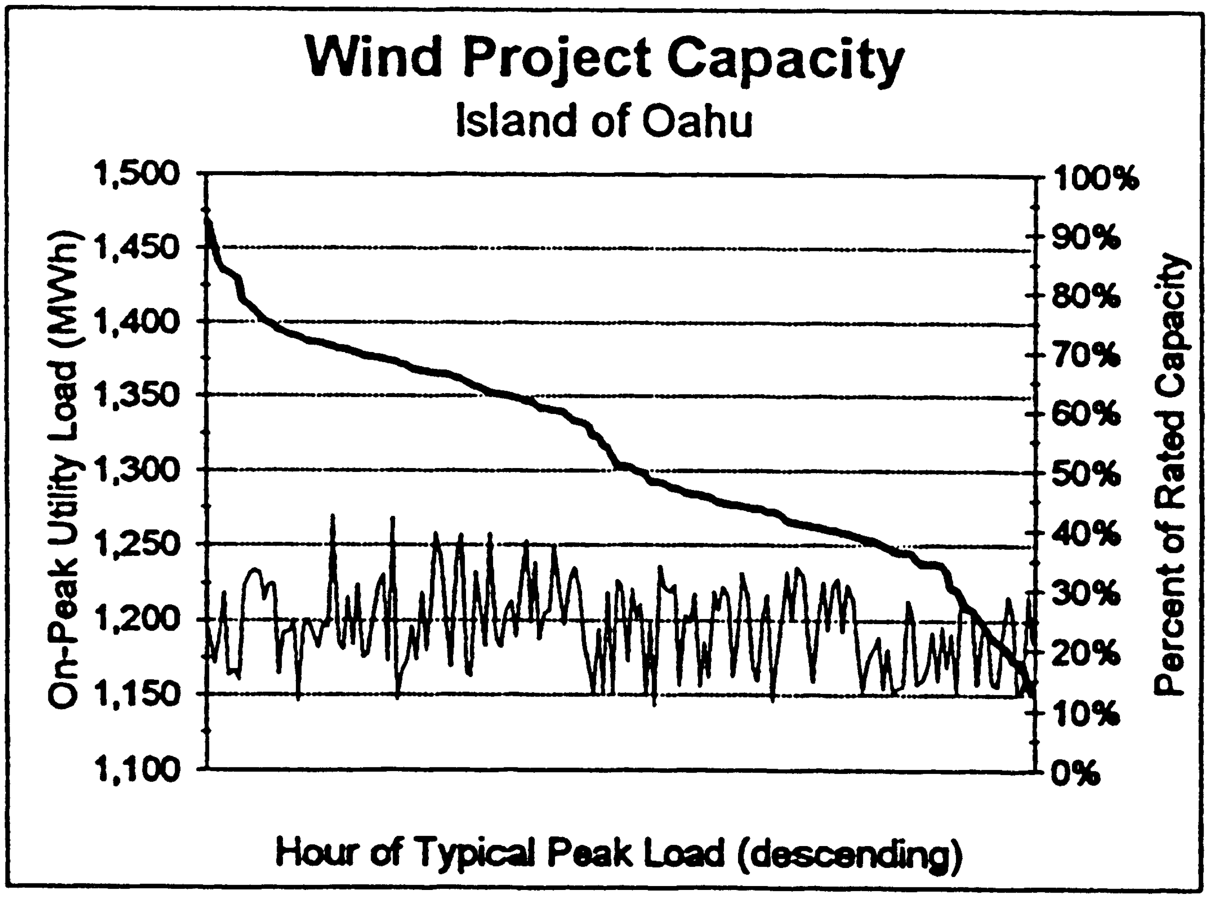


Figure 4-5. Peak Load versus Rated Capacity, Wind

Tables 4-1 to 4-4 show minimum and average capacity values for representative wind, solar, and wave projects on each island. The values are presented on both a monthly and annual basis. Because the wind projects exhibit varying diurnal patterns depending on the site, results for multiple wind energy projects are provided. The solar and wave energy diurnal patterns are similar between sites so only a representative project is shown.

Based on this analysis, there is evidence that wind and wave projects provide capacity value to a utility if minimum rated capacity during peak hours is used as the basis for estimating capacity value. On this basis, solar projects do not have a capacity value. If the average rated capacity during peak hours is used

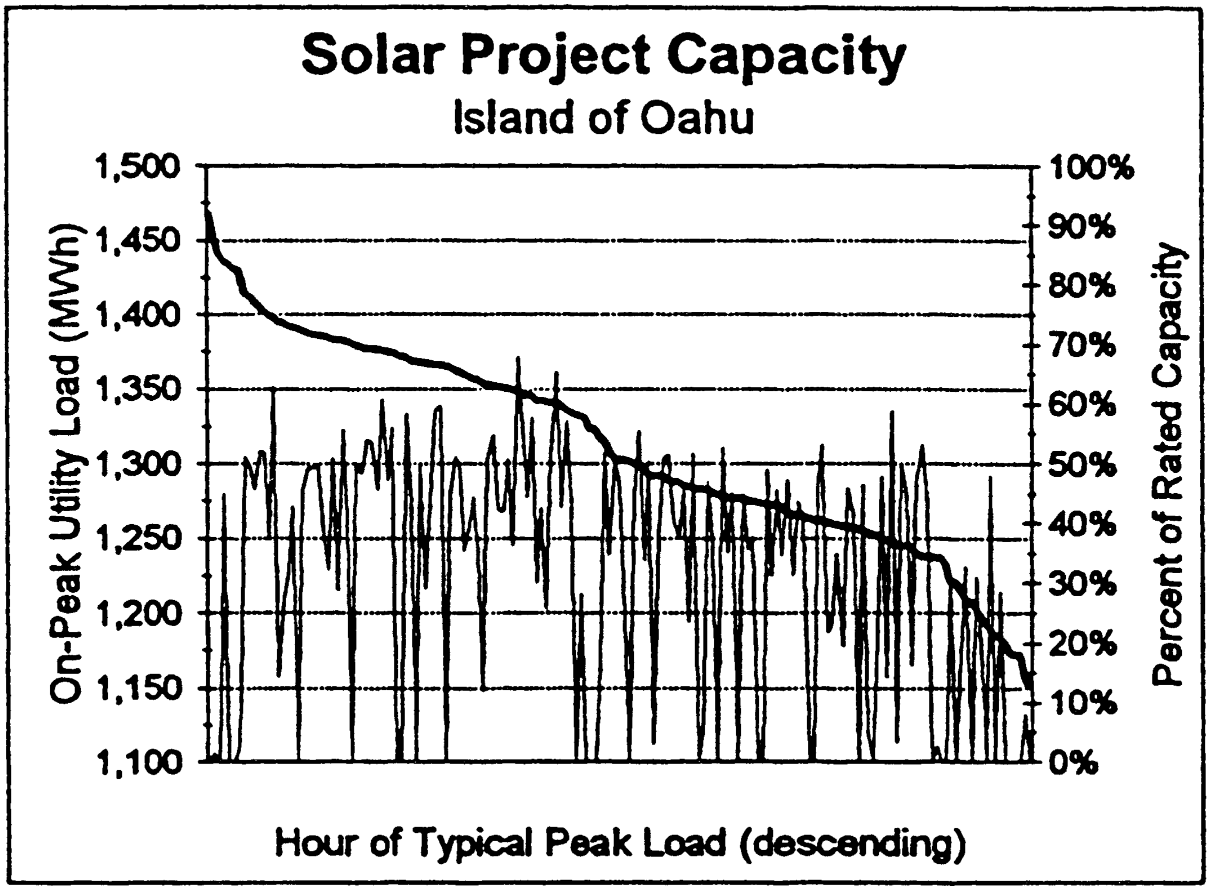


Figure 4-6. Peak Load versus Rated Capacity, Solar

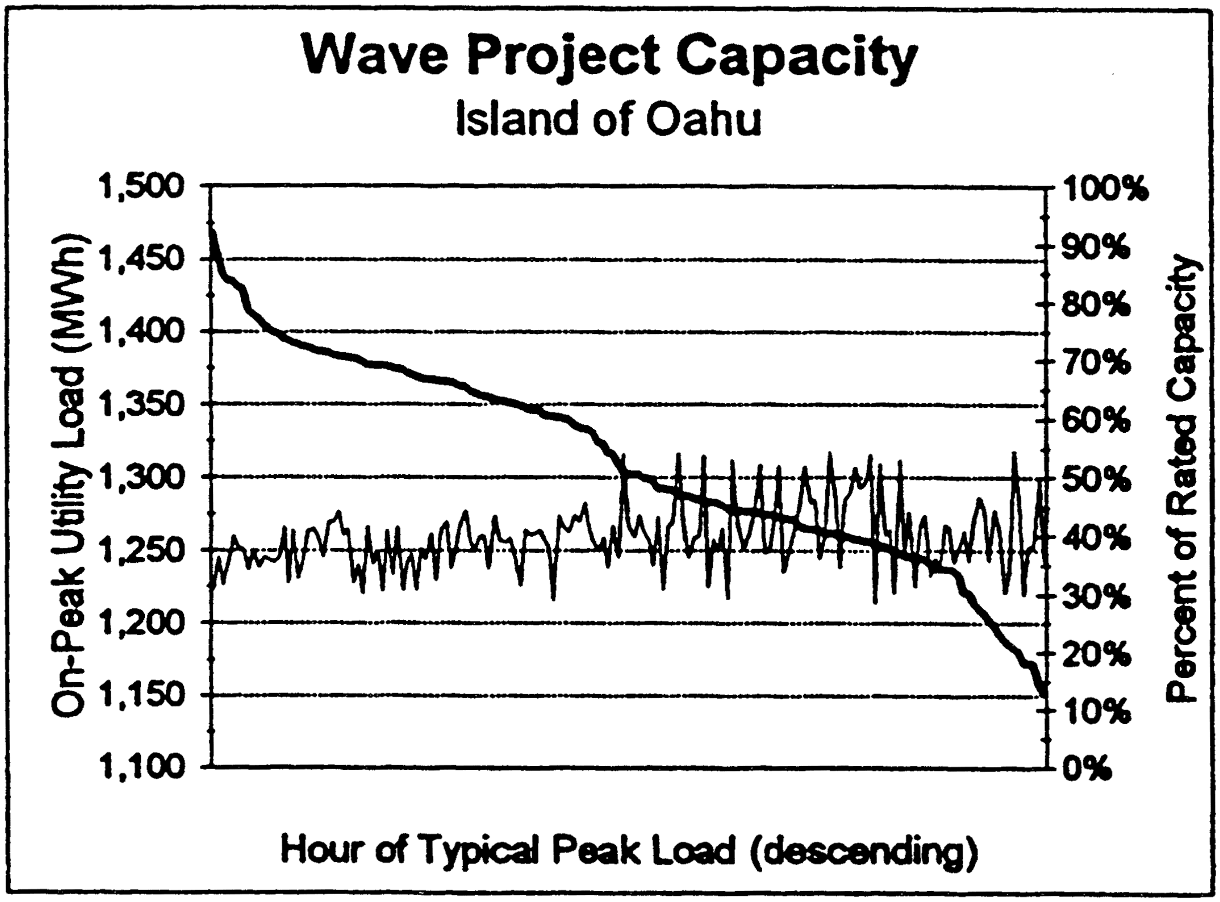


Figure 4-7. Peak Load versus Rated Capacity, Wave

as the basis for estimating capacity value, solar projects have a fairly high capacity value (approximately 25%). This result indicates that although the output from a solar project is not available during the entire peak period, a high percentage of its rated capacity is available during the hours in which it is producing. The range of values for both analyses is fairly broad on a monthly basis as well as between projects. This illustrates the need to evaluate capacity value on a site-specific basis.

TIME-OF-DAY DELIVERY AND PRICING

To evaluate the impact that time-of-day delivery and pricing would have on potential renewable energy project implementation, a comparison of potential project revenues was made under different time-of-day energy delivery and payment scenarios.

Table 4-1. Percent of Capacity During On-Peak Hours, Island of Hawaii

Minimum Diurnal Percent of Capacity During On-Peak Hours

	Wind			Solar Thermal	Wave
	Kahua Ranch	Lalamilo	N. Kohala	N. Kohala	N. Kohala
Jan	31.2%	27.6%	27.5%	0.0%	25.2%
Feb	18.5%	21.6%	28.6%	0.0%	30.5%
Mar	27.3%	33.4%	46.3%	0.0%	38.4%
Apr	29.0%	59.0%	49.8%	0.0%	34.7%
May	17.6%	51.4%	42.3%	0.0%	45.5%
Jun	21.1%	54.9%	47.7%	0.0%	35.2%
Jul	24.6%	48.9%	58.2%	0.0%	35.4%
Aug	25.6%	46.2%	48.1%	0.0%	27.8%
Sep	5.4%	35.3%	33.2%	0.0%	31.4%
Oct	11.4%	31.7%	23.7%	0.0%	33.3%
Nov	28.6%	62.3%	40.4%	0.0%	29.3%
Dec	36.3%	50.1%	53.5%	0.0%	25.6%
Avg	23.0%	43.5%	41.6%	0.0%	32.7%
Max	36.3%	62.3%	58.2%	0.0%	45.5%
Min	5.4%	21.6%	23.7%	0.0%	25.2%

Average Diurnal Percent of Capacity During On-Peak Hours

	Wind			Solar Thermal	Wave
	Kahua Ranch	Lalamilo	N. Kohala	N. Kohala	N. Kohala
Jan	35.3%	32.7%	32.9%	42.4%	28.4%
Feb	23.8%	26.1%	34.4%	32.1%	32.2%
Mar	36.1%	44.5%	56.9%	41.3%	41.2%
Apr	41.2%	65.4%	66.6%	36.5%	36.5%
May	23.9%	57.0%	66.7%	39.2%	46.9%
Jun	29.0%	61.7%	68.5%	32.7%	36.4%
Jul	28.3%	57.2%	73.4%	25.5%	37.5%
Aug	30.3%	54.1%	64.3%	36.3%	31.0%
Sep	9.7%	42.6%	54.1%	48.4%	34.5%
Oct	13.9%	37.4%	30.4%	33.2%	35.6%
Nov	36.8%	66.5%	52.5%	30.4%	33.7%
Dec	42.6%	53.9%	56.9%	35.8%	28.2%
Avg	29.2%	49.9%	54.8%	36.2%	35.2%
Max	42.6%	66.5%	73.4%	48.4%	46.9%
Min	9.7%	26.1%	30.4%	25.5%	28.2%

Table 4-2. Percent of Capacity During On-Peak Hours, Island of Maui

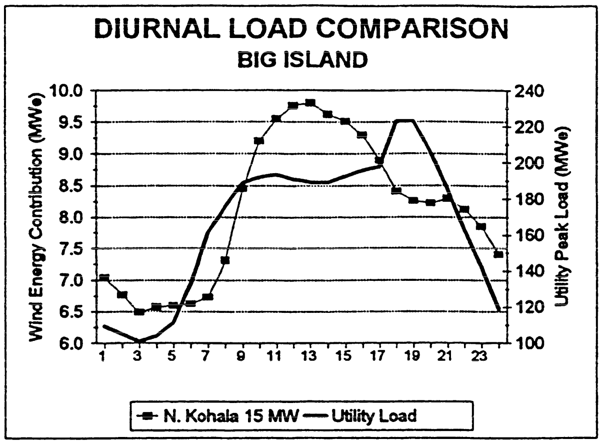
Minimum Diurnal Percent of Capacity During On-Peak Hours

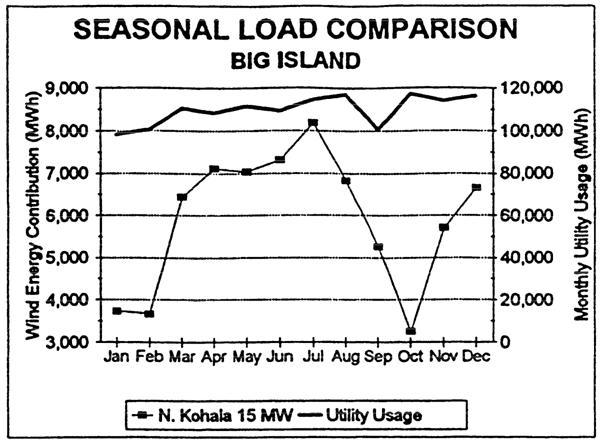
	Wind				Solar Thermal	Wave	
	McGregor Point	NW Haleakala	Puunene	West Maui	Kihei	Opana Point	Waiehu Pt.
Jan	8.5%	6.7%	11.5%	3.5%	0.0%	28.7%	27.4%
Feb	8.7%	6.9%	6.3%	16.0%	0.0%	34.7%	33.2%
Mar	20.9%	18.1%	22.5%	10.2%	0.0%	43.7%	41.8%
Apr	19.8%	16.6%	12.0%	8.4%	0.0%	39.5%	37.8%
May	13.5%	11.0%	3.2%	5.9%	0.0%	51.8%	49.5%
Jun	14.2%	11.1%	9.3%	14.9%	0.0%	40.1%	38.3%
Jul	21.6%	17.4%	8.0%	24.3%	0.0%	40.3%	38.5%
Aug	19.0%	15.6%	2.4%	30.6%	0.0%	31.6%	30.2%
Sep	7.7%	6.2%	0.0%	7.6%	0.0%	35.7%	34.1%
Oct	7.2%	5.9%	0.7%	7.9%	0.0%	37.9%	36.2%
Nov	8.3%	6.5%	5.3%	13.6%	0.0%	33.4%	31.9%
Dec	19.5%	16.5%	18.9%	14.0%	0.0%	29.1%	27.8%
Avg	14.1%	11.5%	8.3%	13.1%	0.0%	37.2%	35.6%
Max	21.6%	18.1%	22.5%	30.6%	0.0%	51.8%	49.5%
Min	7.2%	5.9%	0.0%	3.5%	0.0%	28.7%	27.4%

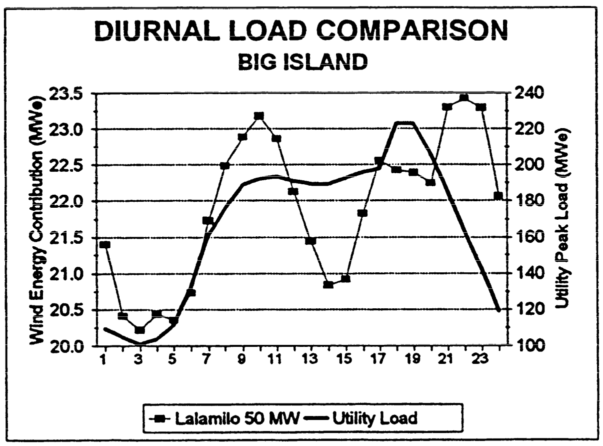
Average Diurnal Percent of Capacity During On-Peak Hours

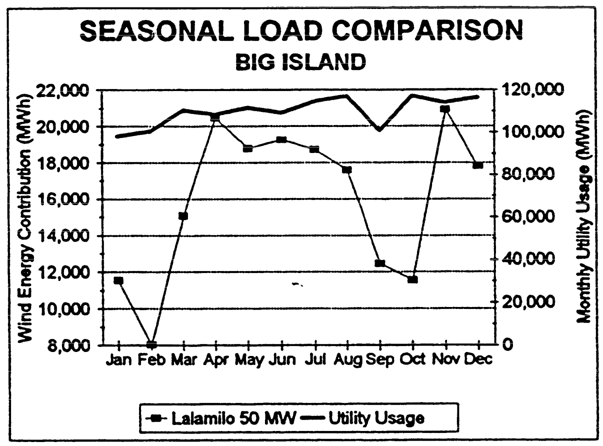
	Wind				Solar Thermal	Wave	
	McGregor Point	NW Haleakala	Puunene	West Maui	Kihei	Opana Point	Waiehu Pt.
Jan	13.7%	11.4%	18.3%	8.3%	30.8%	32.3%	30.9%
Feb	20.3%	17.4%	10.5%	19.1%	25.6%	36.6%	35.0%
Mar	33.7%	29.6%	33.9%	15.3%	26.9%	46.9%	44.8%
Apr	42.5%	37.2%	28.8%	13.9%	33.5%	41.6%	39.7%
May	45.5%	39.9%	21.5%	10.3%	33.9%	53.4%	51.0%
Jun	49.8%	43.8%	29.9%	21.7%	33.0%	41.5%	39.6%
Jul	52.7%	46.7%	30.6%	29.2%	29.5%	42.7%	40.8%
Aug	48.7%	42.7%	22.9%	34.7%	31.0%	35.3%	33.7%
Sep	36.7%	31.7%	34.1%	16.4%	34.1%	39.3%	37.5%
Oct	33.4%	29.1%	10.9%	11.9%	26.0%	40.6%	38.7%
Nov	26.0%	22.2%	24.3%	17.1%	35.3%	38.4%	36.7%
Dec	29.3%	25.1%	27.1%	23.1%	31.2%	32.2%	30.7%
Avg	36.0%	31.4%	24.4%	18.4%	30.9%	40.1%	38.3%
Max	52.7%	46.7%	34.1%	34.7%	35.3%	53.4%	51.0%
Min	13.7%	11.4%	10.5%	8.3%	25.6%	32.2%	30.7%

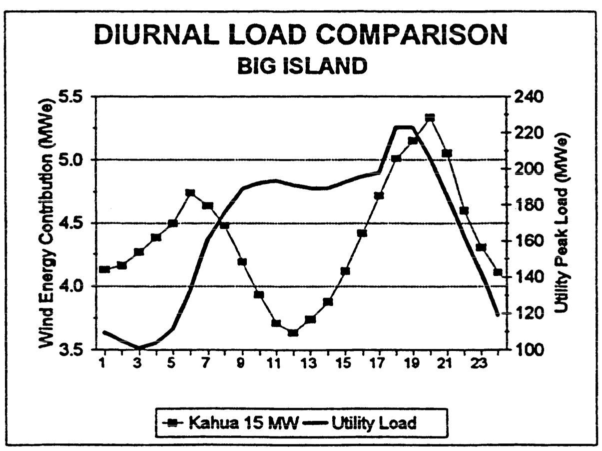
Table 4-3. Percent of Capacity During On-Peak Hours, Island of Oahu











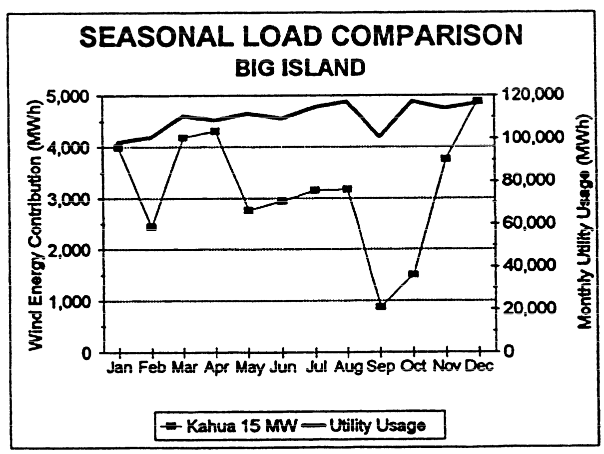


Table 4-4. Percent of Capacity During On-Peak Hours, Island of Kauai

Minimum Diurnal Percent of Capacity During On-Peak Hours

	Wind			Solar Thermal	Wave
	Anahola	N. Hanapepe	Port Allen	Barking Sands	Barking Sands
Jan	12.5%	11.9%	5.1%	0.0%	14.0%
Feb	6.1%	10.6%	11.4%	0.0%	17.0%
Mar	23.7%	25.8%	3.0%	0.0%	21.4%
Apr	12.5%	22.7%	2.8%	0.0%	19.3%
May	7.5%	19.9%	3.8%	0.0%	25.3%
Jun	7.4%	22.4%	11.6%	0.0%	19.6%
Jul	6.8%	26.4%	11.3%	0.0%	19.7%
Aug	5.7%	24.6%	19.1%	0.0%	15.5%
Sep	4.5%	13.3%	9.5%	0.0%	17.5%
Oct	11.3%	18.2%	10.2%	0.0%	18.5%
Nov	19.4%	23.9%	10.5%	0.0%	16.3%
Dec	12.6%	24.7%	23.6%	0.0%	14.2%
Avg	10.8%	20.4%	10.2%	0.0%	18.2%
Max	23.7%	26.4%	23.6%	0.0%	25.3%
Min	4.5%	10.6%	2.8%	0.0%	14.0%

Average Diurnal Percent of Capacity During On-Peak Hours

	Wind			Solar Thermal	Wave
	Anahola	N. Hanapepe	Port Allen	Barking Sands	Barking Sands
Jan	15.1%	16.1%	18.7%	30.5%	15.8%
Feb	8.6%	15.9%	22.1%	24.4%	17.9%
Mar	26.2%	29.3%	27.1%	30.5%	22.9%
Apr	16.9%	27.5%	17.1%	32.7%	20.3%
May	11.2%	26.4%	16.1%	32.8%	26.1%
Jun	11.1%	29.5%	47.2%	34.9%	20.3%
Jul	9.9%	34.5%	40.8%	31.7%	20.9%
Aug	9.5%	28.9%	54.9%	32.1%	17.3%
Sep	7.9%	18.5%	23.6%	43.1%	19.2%
Oct	14.7%	22.1%	14.9%	30.9%	19.8%
Nov	25.9%	29.0%	27.4%	30.9%	18.8%
Dec	14.5%	29.1%	33.2%	22.5%	15.7%
Avg	14.3%	25.6%	28.6%	31.4%	19.6%
Max	26.2%	34.5%	54.9%	43.1%	26.1%
Min	7.9%	15.9%	14.9%	22.5%	15.7%

Table 4-5 contains a summary of the analysis results for each technology type on the island of Hawaii. The results are similar on each island. The table includes one representative project for each intermittent resource technology. Multiple wind projects are included because their diurnal patterns vary and the results vary by project site.

As shown in the table, potential revenues from electricity sales were calculated for each project based on average avoided cost payments and on an assumed time-of-day payment scheme. The time of day payment rates are based on 1993 on-peak and off-peak avoided costs provided by the Hawaiian utilities projected to the year 2005 using a 5% escalation rate. The nature of the results of this analysis are not sensitive to the chosen rate of escalation. Under current practice, the avoided cost payment rate is averaged according to the number of on-peak and off-peak hours experienced by the utility regardless of the timing of energy delivery.

As shown in the table, time-of-day pricing makes a significant difference for the solar technologies. The potential revenues are increased by approximately 7%. This result is consistent with the diurnal energy delivery patterns from a solar project, which illustrates that all the energy is delivered during peak load periods. For wave projects, time-of-day pricing actually decreases the potential revenue from projects. This result illustrates the lack of match with the diurnal utility demand curve. The potential revenues from wind energy projects increases with time-of-day pricing; however, the extent of the increase is fairly small (1%-2%). Time-of-day pricing analysis results from all the intermittent projects on each island are included in Appendix E.

Table 4-5. Energy Payment Comparison, Island of Hawaii

Technology	Type	Location	Project Capacity (MW)	Payment - 2005 Average ($/kWh)	Payment - 2005 Time of Day ($/kWh)	Daily Energy (MWh)	Annual Sales Based on Average	Annual Sales Based on Time of Day	Time of Day Pricing Advantage
Photovoltaic	tracking	Keahole	50	$0.0906	$0.0972	376.5	$12,451,070	$13,355,167	$904,096
Solar Thermal	dish	Waikoloa	30	$0.0906	$0.0973	146.9	$4,857,058	$5,217,107	$360,050
Wave		Honokaa 2A	10	$0.0906	$0.0905	92.0	$3,043,067	$3,041,298	($1,769)
Wave		N. Kohala	30	$0.0906	$0.0905	254.8	$8,427,373	$8,422,474	($4,900)
Wind		Kahua Ranch	15	$0.0906	$0.0906	105.2	$3,478,068	$3,478,090	$22
Wind		Lalamilo Wells	50	$0.0906	$0.0908	525.5	$17,379,153	$17,408,101	$28,948
Wind		N. Kohala	15	$0.0906	$0.0915	194.8	$6,440,754	$6,505,343	$64,589

SECTION 5. RENEWABLE ENERGY IMPLEMENTATION PLAN

As discussed in Sections 2 and 3, the set of projects that were identified as viable in the 1995 and 2005 analyses are viable only as individual projects, not as a group. There are a number of additional factors which impact project implementation that are not considered in the resource supply curve analyses. This section provides an overview of factors that impact the development and implementation of renewable energy projects and presents a plans for integrating renewable energy projects into the state's generation mix by island.

The RSC program ranks projects based on the lowest cost of energy. The projects presented in the previous sections are, in actuality, unlikely to be developed in this order. Although cost effectiveness is certainly one of the primary considerations, other factors will more likely determine the actual development sequence as well as the appropriate project size to be developed. These factors range from subjective considerations, such as the interest of the land owner in leasing the land for a renewable energy project, to more quantifiable considerations, such as the limits imposed on project development due to the energy demand growth rate. Phase 1 of this program included a detailed screening process to eliminate projects with obvious barriers to development and resulted in a list of projects that appear to be technically feasible. Phase 2 provided information on the economic feasibility of these projects. Phase 3 consisted of integrating this information and including consideration of other practical factors that impact the project development to arrive at an implementation plan.

CONSTRAINTS TO RENEWABLE ENERGY PROJECT IMPLEMENTATION

Hawaii has an abundance of renewable energy resources. For most renewable energy technologies, a sufficient resource exists on each island to warrant consideration of an energy project. There are a number of constraints to renewable energy project implementation, however, that are unique to the State of Hawaii. For example, one of the largest factors in eliminating potential projects from consideration in Phase 1 was the availability of land without conflicting or potentially competing land uses. Only on the island of Hawaii and on the lightly populated islands of Lanai and Molokai were sites identified in which the potential for competing land uses were not considered to be an issue. This is not to say that development of projects is impossible on the other islands; only that the demand for land is high and the impact of an energy project on a particular site will be weighed against other potential uses for that land as well as any potential impacts on activities on surrounding lands.

The total generating capacity of the utility grid and the projected demand growth on each island provides the greatest limitation to renewable energy project implementation in the next ten years. Of course, it is possible that renewable energy projects could replace existing fossil fuel plants; however, because the investment in these units has already been committed, this is not expected to be an economical alternative unless fuel prices rise to unprecedented levels, or if some of these fossil fuel plants are retired earlier than expected..

The relatively small size of the utility grids also limits renewable energy potential development, particularly of intermittent generating technologies. Although a number of studies have indicated that penetration limits of intermittent generating resources can meet or exceed 20% of the peak demand without operating penalties, results of such analyses are extremely variable and require detailed load flow and system stability analyses based on specific grid conditions to ensure utility reliability is achieved under all operating conditions. While such detailed utility analyses are beyond the scope of this study, the wealth of potential renewable energy project development opportunities identified by this work should serve to encourage these activities by utilities and other interested parties.

Public acceptance is another constraint to development that is difficult to quantify. Public opinion surveys show a clear preference for renewable energy projects over conventional generation technologies; however, the vast majority of all development projects are subject to some type of public opposition.

DEVELOPMENT OF RENEWABLE ENERGY PROJECT IMPLEMENTATION PLAN

The renewable energy projects that are viable under the set of assumptions presented have been summarized and prioritized in terms of which technologies and project sites hold the greatest promise for assimilation into each island's electrical grid. Renewable energy integration plans were developed based on the 2005 resource supply curve results and consideration of the constraints to implementing renewable energy projects that are discussed above. In developing the renewable energy integration plan, the following process was considered.

The primary consideration for a renewable energy integration plan is the projected load growth on each island. Table 5-1 summarizes the peak load and estimated electricity sales for 1995 and 2005 for each island. As shown in the table, the amount of renewable energy that can be integrated into each utility in the next ten years is bounded by the projected load growth. Note that existing units could be retired or replaced by renewable energy projects if this appeared to be economically feasible; however, that would be the subject of a different analysis.

Table 5-1. Peak Load and Estimated Electricity Sales

	Hawaii	Maui	Oahu	Kauai
2005 Peak Load (MW)	223.0	229.5	1,467.2	84.6
Estimated Energy Sales - 1995	957,013	880,956	6,950,000	398,699
Estimated Energy Sales - 2005	1,416,614	1,042,711	8,550,887	568,304
Growth (MWh)	459,601	161,755	1,600,887	169,605
Maximum Intermittent (20%)	44.6	45.9	293.4	16.9

The penetration limit for intermittent renewable resources is another major consideration in determining the appropriate renewable energy project mix. Previously conducted, generalized studies in Hawaii have indicated that a practical cumulative intermittent resource penetration limit on each of the isolated island utility systems can be estimated at 10% of the annual peak load without operating penalties. As previously discussed, more detailed studies are required to determine appropriate levels above this estimate and given the large number of economically viable, intermittent renewable energy projects, such studies are immediately warranted. It is anticipated that such studies will permit higher penetration limits on each island, particularly given the likelihood of more efficient utility operating practice by 2005, expected technological improvements in the generating equipment, and the availability of more detailed energy production estimates for the proposed projects. As a result of these considerations, a penetration limit of 20% of peak load was assumed for the purposes of developing an integration plan. These values are also provided for each utility in Table 5-1.

The value of 20% as a maximum penetration limit was chosen in anticipation of likely results from more detailed studies of the power system of each island. It should be noted that intermittent renewable energy projects such as wind and run-of-river hydro may not produce at their rated capacity at any given time. Combinations of intermittent renewable energy projects in any system are even less likely to produce at their combined rated capacity. By considering such combined effects, or possible other operating strategies, detailed studies may even allow levels of intermittent renewable energy development higher than 20%.

The relative cost of energy for the renewable projects was the next major consideration in determining the appropriate renewable energy plan on each island. The projects that appeared to be economically viable under the conservative scenarios were considered first. The most economic project size (generally the largest) was included if the assumed penetration limits (for intermittent technologies) and/or the load growth limits had not yet been exceeded. Nominal scenarios and then optimistic scenarios were then evaluated to determine the additional projects sites, technologies, and project sizes that were appropriate to consider in the analysis.

Prioritized projects are summarized for each of the islands in the following sections. In all cases, the integration plans include intermittent projects totaling less than 20% of the annual peak load. Even with this limitation, it appears feasible to meet all new generating requirements in the next ten years with renewable energy additions. This is a valid objective for the State of Hawaii to consider.

The recommended integration plan provided for each island represents realistic goals that can be easily achieved if reducing the oil dependency is a priority for both the government and the utilities. Should conditions occur such as changes in the operating characteristics of the utilities, incorporation of energy storage, widespread use of electric vehicles, or island interconnection, significantly more renewable energy could be incorporated into the generation mix. As a result, the projects listed in the previous sections are all considered viable options for the future, even if they are not discussed in the integration plans.

ISLAND OF HAWAII

Table 5-2 presents the recommended renewable energy integration plan for the island of Hawaii. The table includes a prioritized list of renewable energy projects, their location, rated capacity, and potential energy contribution. The table also summarizes the estimated peak load for 2005 and the energy demand increase that is projected to occur between 1995 and 2005 for Hawaii. Projects were included in the integration until the cumulative energy contributions from all the recommended projects met or exceeded the projected demand increase.

As previously discussed, the total capacity of intermittent technologies such as wind was restricted to 20% of the peak load for 2005. As a result, only 45 MW of wind energy projects are included in the plan. Additional wind energy development is possible if conditions are shown to allow a higher penetration. The North Kohala project was chosen because it is the most cost-effective wind energy project on the island. Inclusion of this project limits additional development at Lalamilo (the next most cost-effective project) to 30 MW in order to remain within the assumed penetration limits. Note that a larger project at Lalamilo is feasible as is a project at Kahua Ranch, should the North Kohala project be undevelopable for factors other than cost.

Table 5-2. Renewable Energy Integration Plan, Island of Hawaii

2005 Peak Load		**223.0**	**MW**
Estimated Energy Demand Increase		**459,601**	**MWh**
20% of Peak Load*		**44.6**	**MW**
Technology	**Location**	**Capacity (MW)**	**Energy Contribution (MWh)**
Wind	N. Kohala	15	71,178
Wind	Lalamilo	30	115,714
Geothermal	Kilauea	50	362,314
Hydroelectric	Umauma Stream	13.8	40,199
Total Renewable Energy		**108.8**	**589,405**

*Penetration limit for intermittent resources
Note: Energy contribution values are based on nominal energy projection estimates.

The hydroelectric project on Umauma Stream is the next project included in the plan. Implementation of this project may be hindered by public opposition; however, its energy contribution is relatively small and if it is not considered, the output from the remaining projects would still exceed the projected demand increase.

A geothermal project in the Kilauea East Rift Zone is also included in the plan. The 50 MW project size is included because it is more cost effective than the 25 MW size even though the annual energy production from this project results in a combined total far greater than the anticipated demand increase. In the event that further geothermal development on the island is not able to proceed in the desired time frame, a biomass project located on the Hilo Coast or other locations could meet the same need for firm generating capacity.

Island of Maui

Table 5-3 presents the recommended renewable energy integration plan for the island of Maui. The table includes a prioritized list of renewable energy projects, their location, rated capacity, and potential energy contribution. The table also summarizes the estimated peak load for 2005 and the energy demand increase that is projected to occur between 1995 and 2005 for Maui. Projects were included in the integration until the cumulative energy contributions from all the recommended projects met or exceeded the projected demand increase.

Although there is some resource uncertainty at the site, a wind project at McGregor Point is the most cost-effective project on Maui. A wind project on the northwest slope of Haleakala is also included in the plan. Additional wind projects at other sites are also feasible and could replace these two if they should prove to be undevelopable for factors other than cost.

A biomass project using organic waste as the fuel source is also included in the plan. This project assumes that a revenue stream similar to tipping fees is available to the project. A biomass electric project using tree crops as the fuel source would be the next project to be included if the assumption about tipping fees proves to be inaccurate.

Table 5-3. Renewable Energy Integration Plan, Island of Maui

2005 Peak Load		**229.5 MW**	
Estimated Energy Demand Increase		**161,755 MWh**	
20% of Peak Load*		**45.9 MW**	
Technology	**Location**	**Capacity (MW)**	**Energy Contribution (MWh)**
Wind	McGregor Point	10	24,611
Biomass - organic waste	Puunene	25	153,300
Wind	NW Haleakala	30	56,140
Total Renewable Energy		65	234,051

*Penetration limit for intermittent resources
Note: Energy contribution values are based on nominal energy projection estimates.

Island of Oahu

Table 5-4 presents the recommended renewable energy integration plan for the island of Oahu. The table includes a prioritized list of renewable energy projects, their location, rated capacity, and potential energy contribution. The table also summarizes the estimated peak load for 2005 and the energy demand increase that is projected to occur between 1995 and 2005 for Oahu. Projects were included in the integration until the cumulative energy contributions from all the recommended projects met or exceeded the projected demand increase.

Because Oahu has a significantly higher energy demand than the other islands, a large number of projects are included in the integration plan. Unlike Hawaii and Maui, where there are a number of viable integration plan possibilities, the demand increase on Oahu requires consideration of the majority of projects that are considered to be viable under the optimistic scenarios. If only projects that were shown to be viable under nominal conditions were included in the plan, they would only be able to contribute 30% of the demand increase.

A biomass electric project using organic waste as the fuel source is the most economical project on Oahu. A waste-to-energy facility is already in operation on this island and this facility could be located in the same region to take advantage of existing transportation plans. Wind projects at Kaena Point and Kahuku are also included in the plan at their largest size. These three projects are viable even under nominal conditions.

Additional projects included in the plan include significant quantities of photovoltaics, solar thermal, biomass electric, and wave energy generation. Although these projects are all viable under optimistic assumptions, their development status is more uncertain. Due to their significant energy contribution potential, however, they should be seriously considered as future alternatives.

Table 5-4. Renewable Energy Integration Plan, Island of Oahu

2005 Peak Load		**1,467.2 MW**	
Estimated Energy Demand Increase		**1,600,887 MWh**	
20% of Peak Load *		**293.4 MW**	
Technology	**Location**	**Capacity (MW)**	**Energy Contribution (MWh)**
Biomass-organic waste	Barbers Point	50	306,600
Wind	Kaena Point	15	31,558
Wind	Kahuku	80	151,558
Solar Thermal - dish	Pearl Harbor	50	84,942
Solar Thermal - dish	Laulaulei	50	80,912
Photovoltaic - tracking	N. Ewa Plain	50	111,675
Biomass - grass crops	Waialua	25	153,300
Wave	Makapuu	60	224,378
Wave	Kahuku Point	60	211,197
Wave	NE Coast	60	205,535
Total Renewable Energy		**500**	**1,609,130**

*Penetration limit for intermittent resources

Note: Energy contribution values are based on nominal energy projection estimates.

Island of Kauai

Table 5-5 presents the recommended renewable energy integration plan for the island of Kauai. The table includes a prioritized list of renewable energy projects, their location, rated capacity, and potential energy contribution. The table also summarizes the estimated peak load for 2005 and the energy demand increase that is projected to occur between 1995 and 2005 for Kauai. Projects were included in the integration until the cumulative energy contributions from all the recommended projects met or exceeded the projected demand increase.

Table 5-5. Renewable Energy Integration Plan, Island of Kauai

2005 Peak Load		**84.6 MW**	
Estimated Energy Demand Increase		**169,605 MWh**	
20% of Peak Load*		**16.92 MW**	
Technology	**Location**	**Capacity (MW)**	**Energy Contribution (MWh)**
Wind	N. Hanapepe	10	22,602
Wind	Port Allen	5	9,321
Hydroelectric	Wailua River	6.6	16,435
Biomass - tree & organic waste	Kaumakani	25	153,300
Solar Thermal - dish	Barking Sands	10	17,250
Total Renewable Energy		**56.6**	**218,908**

*Penetration limit for intermittent resources

Note: Energy contribution values are based on nominal energy projection estimates.

The integration plan for Kauai includes a wide variety of technology types. Wind projects are viable in two locations under conservative conditions. As with the hydroelectric project on Hawaii, this technology is subject to public opposition. It is included in the plan for its cost-effectiveness; however, its contribution is relatively small and if it is not considered, the output from the remaining projects would still exceed the projected demand increase.

The next most cost-effective project included in the database is a 50 MW biomass electric project at Kaumakani including both tree crops and organic waste as the fuel source. A 50 MW project is too large to be considered by 2005. As a result, a 25 MW project was included in the plan even though this project size was not included in the database. A 25 MW project using only tree crops as a fuel source was considered at Lihue and this project could also feasibly be included in the plan; however, the Lihue biomass project is less cost effective than a solar thermal project at Barking Sands under nominal conditions. As a result, the solar thermal projects and a smaller biomass project at Kaumakani were included in the plan.

OPPORTUNITIES FOR SMALL-SCALE RENEWABLE ENERGY PROJECT IMPLEMENTATION

Small-scale renewable energy projects are also well suited for the islands, particularly Lanai and Molokai, where limited demand restricts utility-scale development yet also results in high energy costs. Small-scale renewable energy projects, either through demand-side or dispersed-generation applications, should be economical on a widespread basis and have the potential to make a significant contribution to reducing petroleum dependency. Although small-scale projects are likely to be possible at many locations on each island, the larger projects described for the larger islands will make a more substantial contribution. Nonetheless, these opportunities should be pursued to the greatest extent possible.

The economics and market potential for small-scale renewable energy applications is difficult to quantify. The economics are dependent on the costs of alternative sources of supply which are extremely site specific. For isolated users, the economics are usually compared to the cost of grid extension. For grid-connected users, the economics are dependent on the cost of electricity and the power purchase terms available to sell any excess generation to the utility.

Promising applications for small-scale renewable energy projects that may be feasible for locations in Hawaii include dispersed generation, demand-side, off-grid, and grid support projects. These small-scale applications may be viable for both residential and commercial or industrial energy users. Although it was beyond the scope of this study to estimate the market potential for each of the applications, RLA developed representative project costs and performance estimates for a number of the most promising small-scale renewable energy applications on Hawaii. These “case studies,” which include a description of the potential application, cost and performance summaries, and references for additional information, are included in Appendix F.

Other case studies presented illustrate promising applications for using the near shore cold water resource. Note that even in the 2005 optimistic case the levelized cost of energy for a closed cycle OTEC power plant at Keahole Point is 12.5 cents per kWh. Services available from open cycle desalination and deep seawater cooling can be more economically competitive than their conventional alternates (see Appendix F for details).

SECTION 6. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Renewable energy projects can provide all the new generation required to meet projected energy demand increases between 1995 and 2005. On Maui, this can be accomplished with projects that are cost competitive even under the most conservative assumptions. On Hawaii and Kauai, this can be accomplished with projects that are cost competitive under nominal scenarios. If conservative assumptions are used, Hawaii and Kauai can still obtain 50% and 25% of the projected energy demand growth from renewable energy projects, respectively. On Oahu, under nominal assumptions, renewable energy projects can provide over 30% of the new generation required to meet energy demand increases and under optimistic conditions, all the energy required to meet energy demand increases.

Based on these results, it is a realistic goal for the State of Hawaii to add only renewable energy projects to meet future energy demand growth between 1995 and 2005 and even beyond. It is appropriate to begin working on this goal immediately because several projects are cost competitive now.

Under optimistic assumptions, enough energy could be produced from renewable energy projects to meet most, if not all, the electricity requirements on Maui, Hawaii, and Kauai. Constraints to project implementation, conventional generation units already in place, and projected demand growth make this result unrealistic. It does illustrate, however, that under optimistic circumstances, investments in conventional fossil fuel plants will turn out to be uneconomical in the future. This conclusion is supported by both the 1995 results that indicate that there are already substantial investments in renewable energy resources that are more economical than the avoided energy cost from fossil fuel technologies (the basis for avoided cost); and by the nominal case calculation presented for 2005.

At the other extreme, conservative scenarios provide a minimum number of projects that should be considered and implemented in the state. Because investors have experienced financial losses due to excessively optimistic assumptions for renewable energy projects in the past, they may be inclined to lean towards the conservative estimates. Nonetheless, a number of viable projects exist even under this scenario. These projects can be pursued with a high confidence level in their costs and conservative performance estimates and with a minimum amount of risk to the investor. If the projects identified as viable in 1995 and those that are viable in 2005 under conservative conditions are installed as soon as possible, the experience gained from these projects will help narrow the range of projected development cost estimates for other projects installed in the future.

The annual savings benefits shown in the tables in this report for the 2005 scenario may be unrealistic because they are based on a comparison with projected avoided energy cost. The magnitude of the benefit is not as important as the fact that there is indeed a benefit in implementing renewable energy projects over continuing with the current practice of relying heavily on fossil fuel. There are other benefits also which have not been included in the data presented. Employment benefits would flow to the residents of the state because construction and operation of renewable energy projects involve more labor than for comparatively sized fossil fuel plants. A greater use of Hawaiian resources also insulates the state from fuel price escalation. Furthermore, the obvious environmental advantages of using renewable energy have not been incorporated into the results.

RECOMMENDATIONS

Whether the projects are evaluated based on the optimistic, conservative, or nominal scenarios plays a big part in determining the pace of renewable energy development in Hawaii. Many renewable technologies have developed at a slower rate than historically projected. On the other hand, the extent of commercial wind energy development over the last ten years provides a good illustration of the speed in which renewable energy technologies can mature. This is in part driven by research and development funding levels and other policy choices. Although the nominal cases represent the most reasonable estimates, both the optimistic and conservative cases are possible scenarios – neither represents an unrealistic extreme.

Economic conditions unrelated to the pace of technology development will also be a major factor in determining the level of renewable energy integration in Hawaii. Avoided cost levels or power purchase contract terms will play a large role in determining the projects that are developed. Although the state cannot control the price of oil, it can influence the power purchase contract terms that are available to independent power producers. In addition to encouraging utilities to construct contracts with favorable terms for renewables, the state must also allow the costs associated with these contracts to be included in the utility's rate base. Factors that have been shown to be favorable to renewables include consideration of capacity value and time-of-day pricing. Contract structures that assist in obtaining financing at favorable rates (such as front loaded contracts and long-term contracts with specified payment schedules) will also promote renewable energy integration.

The state can also continue to support and encourage research and analysis that promote renewable energy implementation. Because a significant number of additional renewable energy projects could be developed if not for the penetration limits for intermittent technologies on isolated grids, studies addressing this issue should be a priority. Because such studies require a significant level of effort and detailed information about utility system characteristics, these analyses should be conducted in cooperation with the utilities.

Energy storage options, if economical, would also address the penetration limits issue. It is recommended that the costs and operation of promising energy storage possibilities be evaluated to determine if such technology is viable. An evaluation conducted with the same approach and economic methodology as the resource supply curve data would facilitate the evaluation.

For the projects that appear to be viable based on the results of this program, detailed feasibility studies can be performed to further refine their costs and performance. These activities may be carried out by a developer, utility, or government agencies interested in the project development.

Additional resource assessment and technological research would address the uncertainty in the estimates and reduce the range between conservative and optimistic estimates. Resource assessment should focus on areas in which insufficient data are available to accurately define performance. For example, wave energy projections are particularly broad and resource assessment activities would greatly reduce the performance uncertainty. Wave energy projects would also benefit from technological research. Wave projects had significant potential for Hawaii under the optimistic scenarios but were extremely costly under conservative assumptions. Demonstration projects or practical research geared toward commercial development could provide more confidence in the cost and performance of these technologies.

For wind projects, a number of viable projects already exist. On Hawaii and Maui, more electricity can be generated by wind projects than the utility can accept. On Oahu, large-scale projects have been identified and additional wind projects are unlikely because of land use constraints. As a result, additional resource assessment activities should be geared towards micrositing for the specific projects already identified or establishing long-term reference stations to support project development and operation. Because such limited wind resource data exist on Kauai, additional data collection to identify sites may be valuable. At a minimum, monitoring should continue at the promising sites.

Although wind projects could also benefit from research activities, achieving cost and performance improvements is not necessary to make these projects viable under even the most conservative assumptions. As a result, wind energy project integration will likely benefit more from policy initiatives such as facilitating the permitting requirements or establishing financeable power purchase contracts than they will from research.

A number of solar technology projects are close to being cost-effective under nominal conditions. Both solar thermal dish projects and photovoltaic tracking projects are close enough to being viable that they warrant serious consideration. Capacity credit, time-of-day pricing, or tax credit changes could result in these projects being viable generation options in the next ten years even under nominal or conservative conditions. Hawaii could assist in the development of these technologies by participating in demonstration projects or research activities. Hybrid systems that utilize gas, biomass, or other fuel in conjunction with solar thermal heat are receiving considerable attention and may hold promise for Hawaii applications. These systems can operate as firm generating resources. At a minimum, the technology improvements should be tracked and incorporated into planning processes. Solar thermal troughs do not appear to be viable options for development in Hawaii.

Biomass electric and biomass fuels are both promising technologies for Hawaii and their development and implementation should be pursued. In addition to offering the only firm renewable energy option that is economically viable, biomass plantations allow the state to preserve a portion of its land in agricultural crops which provides valuable benefits to the state's residents as well as promotes the tourist industry. Although biomass fuels were not the primary focus of this study, results indicate that the costs are in the general range of expected market prices for fuel alternatives. Biomass fuels offer the additional benefit of being transportable.

Hydroelectric and geothermal projects are commercially viable in Hawaii today; however, a limited number of developable sites exist. Their development is also subject to significant public opposition. Additional resource assessment or research is unlikely to change the analysis results. The projects identified in this study should be pursued to the extent in which they are viewed as acceptable to the public.

Although only two ocean thermal projects were evaluated in this project, neither was shown to be cost effective even in the most optimistic case. Although ocean thermal technology may offer a significant contribution to Hawaii's generation mix in the long-term, it does not appear at this time that it will be competitive with other renewable energy options in the next ten years.

APPENDIX A

RESOURCE SUPPLY CURVES, ISLAND OF HAWAII

APPENDIX B

RESOURCE SUPPLY CURVES, ISLAND OF MAUI

APPENDIX C

RESOURCE SUPPLY CURVES, ISLAND OF OAHU

APPENDIX D

RESOURCE SUPPLY CURVES, ISLAND OF KAUAI

APPENDIX E

TIME-OF-DAY PRICING SUMMARIES

APPENDIX F

CASE STUDIES FOR SMALL-SCALE APPLICATIONS

Photovoltaics in Dispersed Utility Applications
Photovoltaics in Off-Grid Applications
Small-Scale Wind-Electric Applications
Domestic Solar Water Heating
Solar Desalination/Distillation
Solar Thermal Industrial Heat
Ocean Thermal Resource Applications